



Geochemical Exploration in Regolith Dominated Terrains

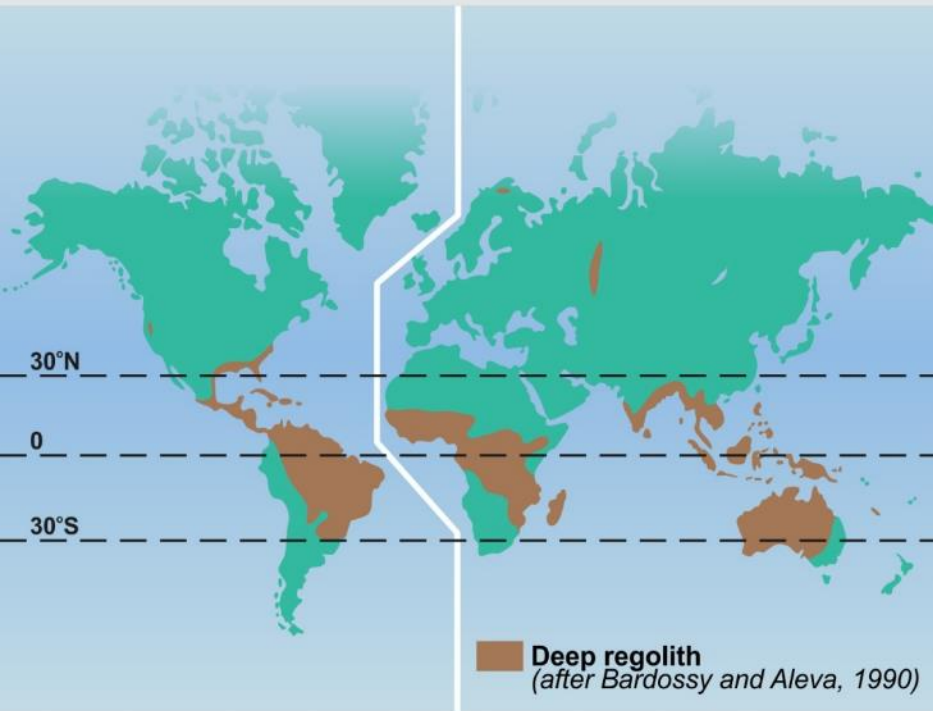
Ravi Anand, Rob Thorne, Walid Salama, Vasek Metelka

MINERAL RESOURCES
www.csiro.au



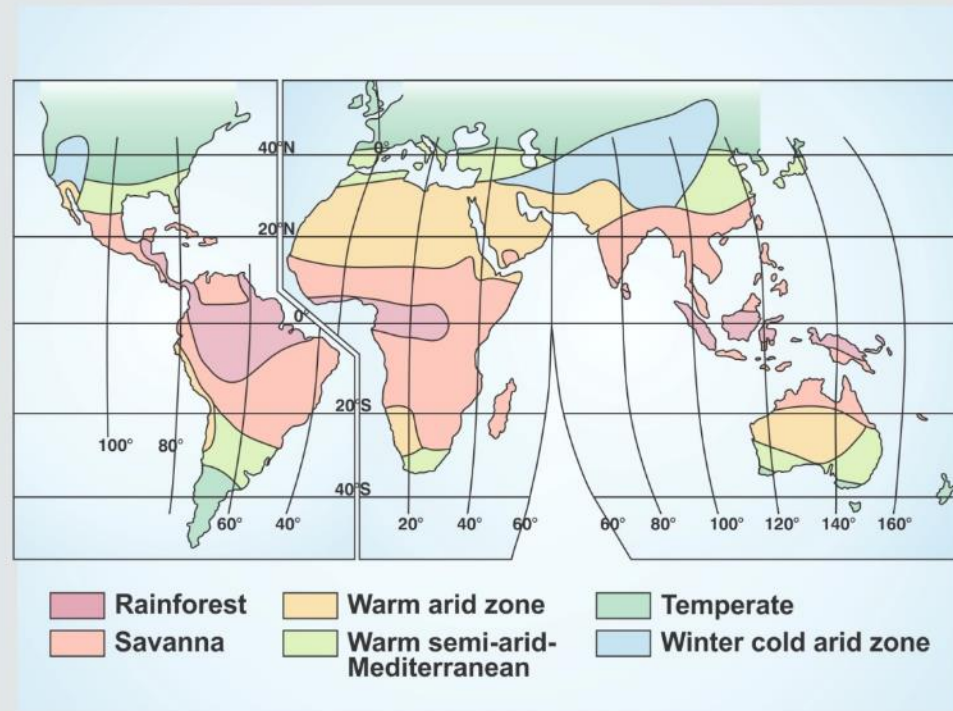
Areas of regolith cover: Issues

DEEP REGOLITH



- Large areas of South America, Africa and Australia are covered with regolith.
- South America and Africa have suffered under exploration relative to indicative mineral potential.
- Regolith may form important sampling media

PRESENT CLIMATE ZONES

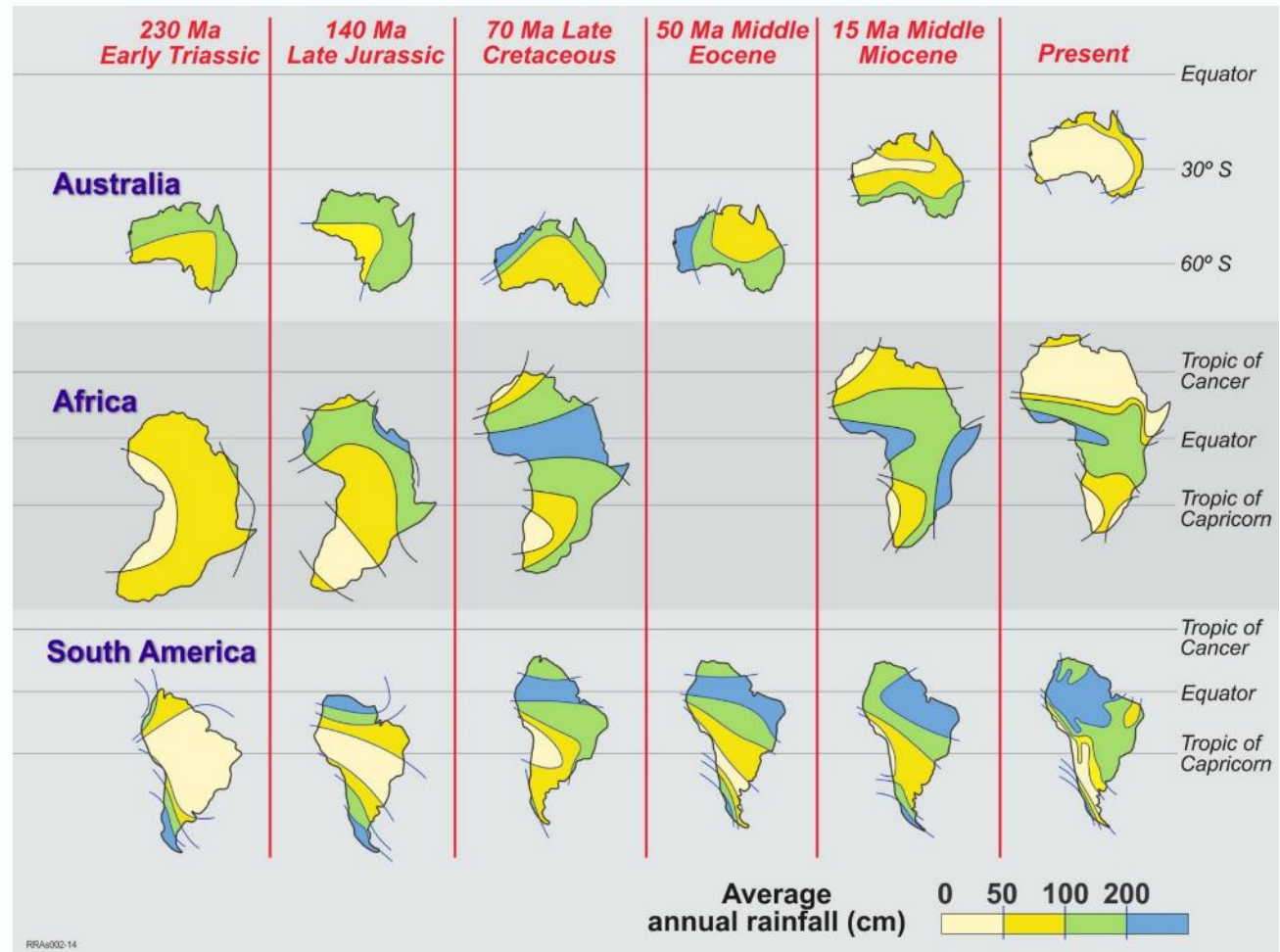


- Limited success because of lack of understanding of regolith-landform formation and metal dispersion processes in various climatic regimes

Palaeoclimatic history of Australia, Africa and South America

Australia has drifted northwards

This resulted in change in climatic conditions from wetter, warmer (tropical) to arid conditions.



Two types of cover: In situ and transported

Bronzewing, Western Australia

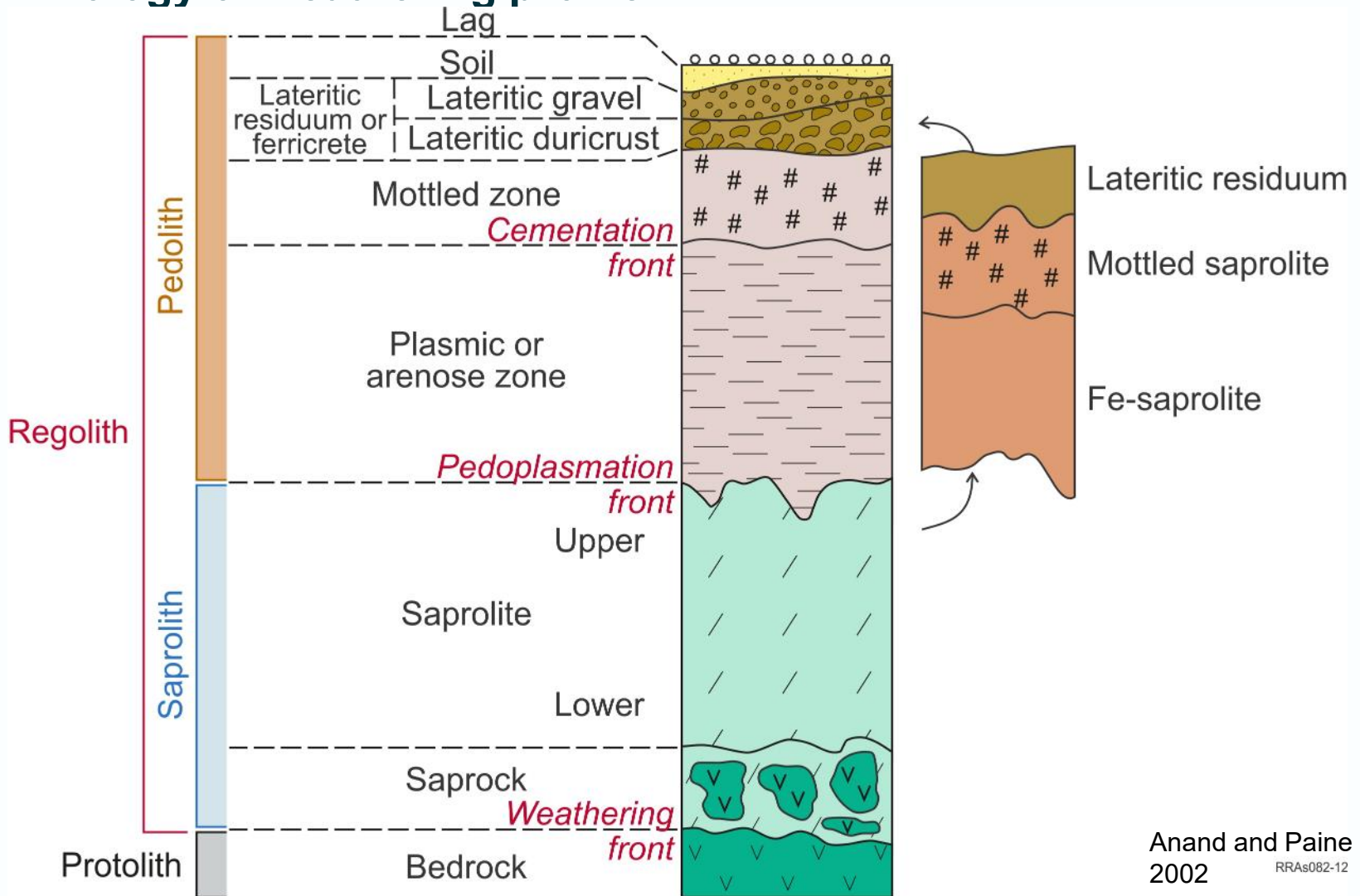


IGARAPÉ BAHIA Carajas, Brazil

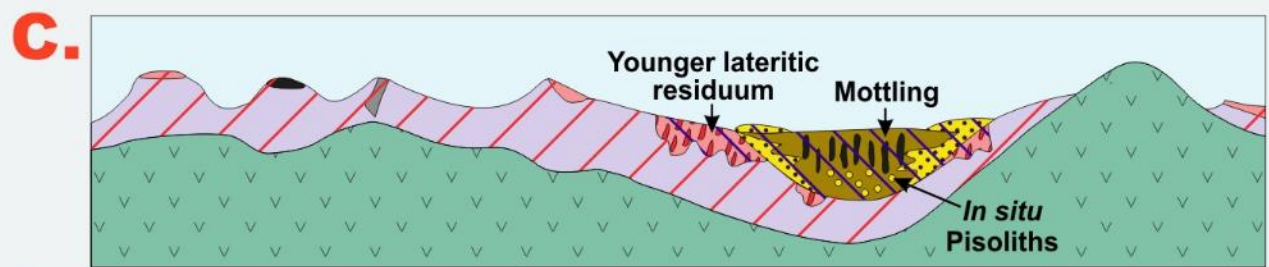
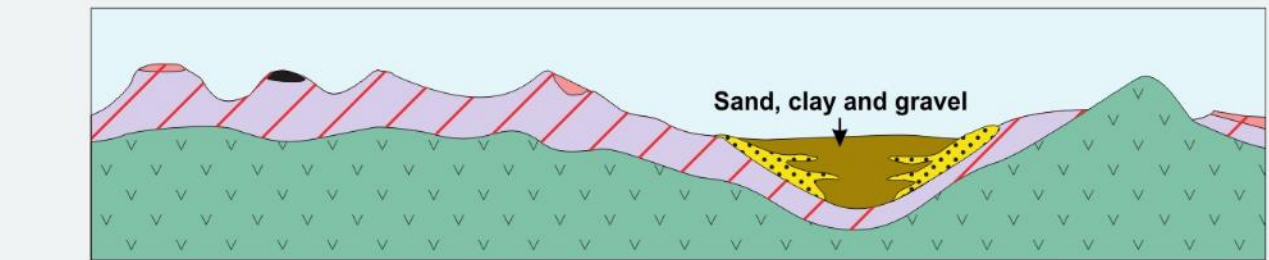
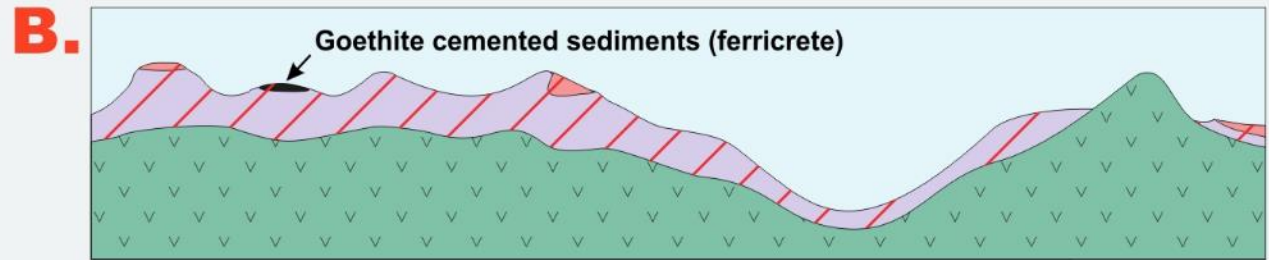
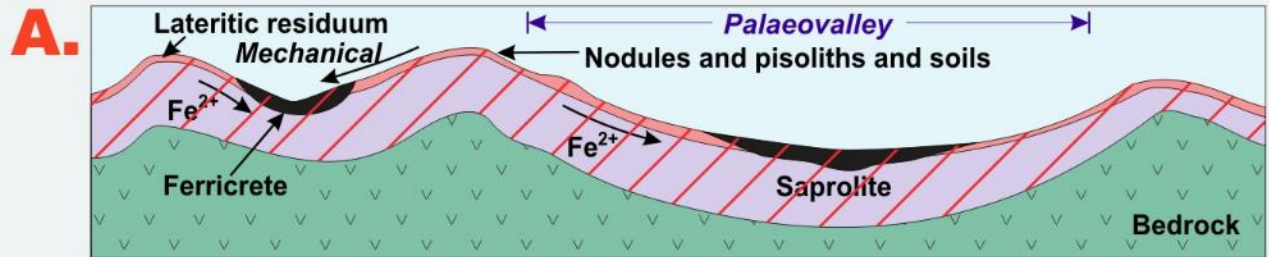


Anand

How to describe regolith materials: Developing consistent and uniform terminology of weathering profile



Anand and Paine
2002
RRAs082-12

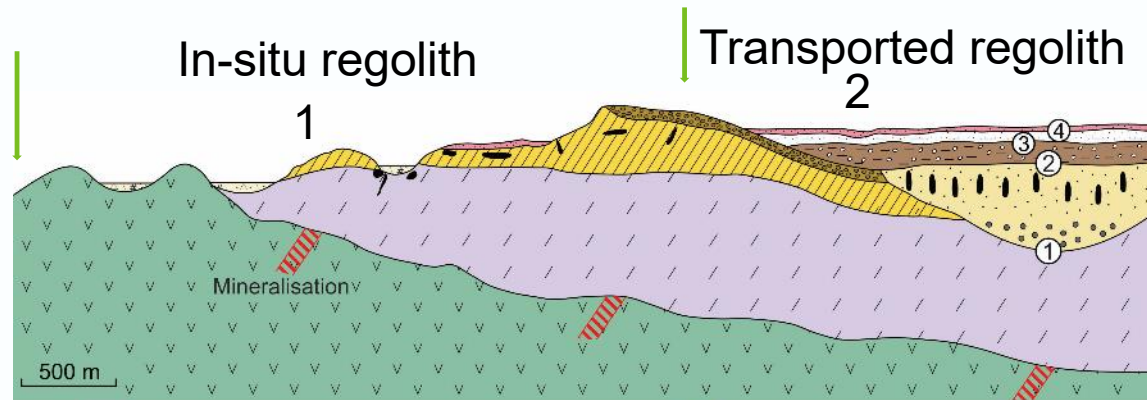


Landscape Model (e.g. Yandal Belt) - Yilgarn Craton

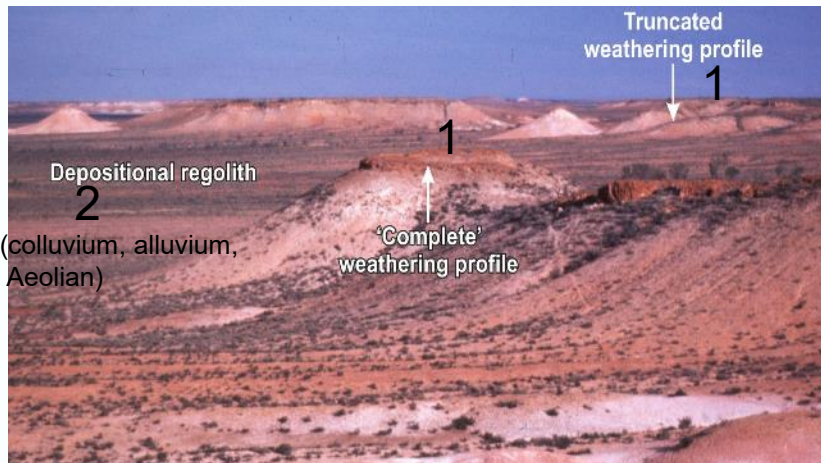
- A.** Pre Tertiary
Weathering
- B.** Early to Mid Tertiary
erosion and
sedimentation
- C.** Mid to Late Tertiary
weathering
- D.** Late Tertiary to
Quaternary
sedimentation and
weathering

Anand and Paine 2002

Variable regolith is exposed at landsurface



Western Australia landscape

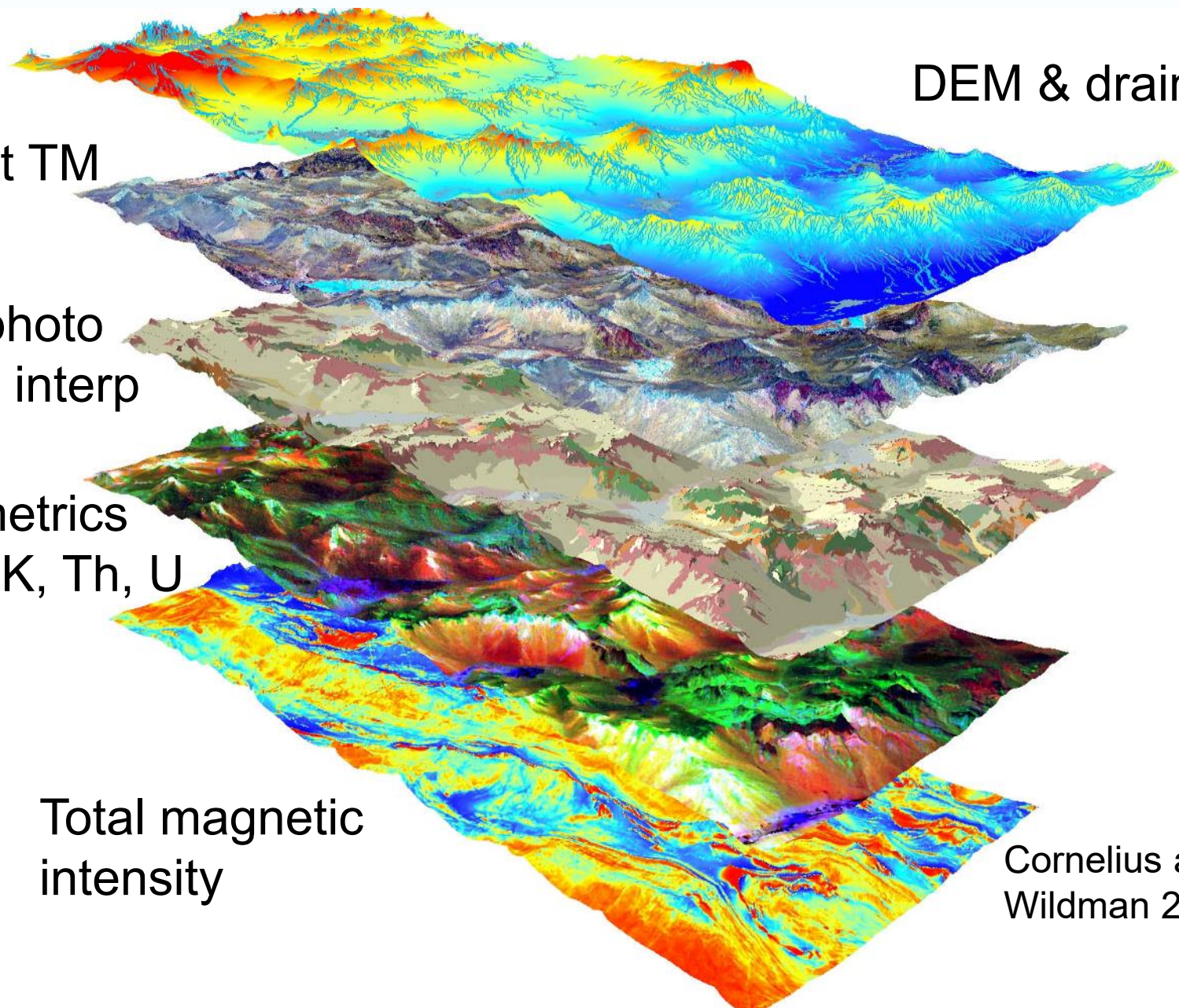


- Acid red sandy soil
- Sandy clay
- Silicified (hardpanned) sandy silty clay
- Hardpanned gravelly sandy clay
- Red, megamottled or bleached palaeochannel clays
- Concentric pisoliths
- Lateritic residuum
- Mottled/ferruginous saprolite
- Iron segregations
- Saprolite
- Bedrock
- Interfaces

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Anand and Paine 2002

REGOLITH MAPPING



DEM & drainage

Landsat TM

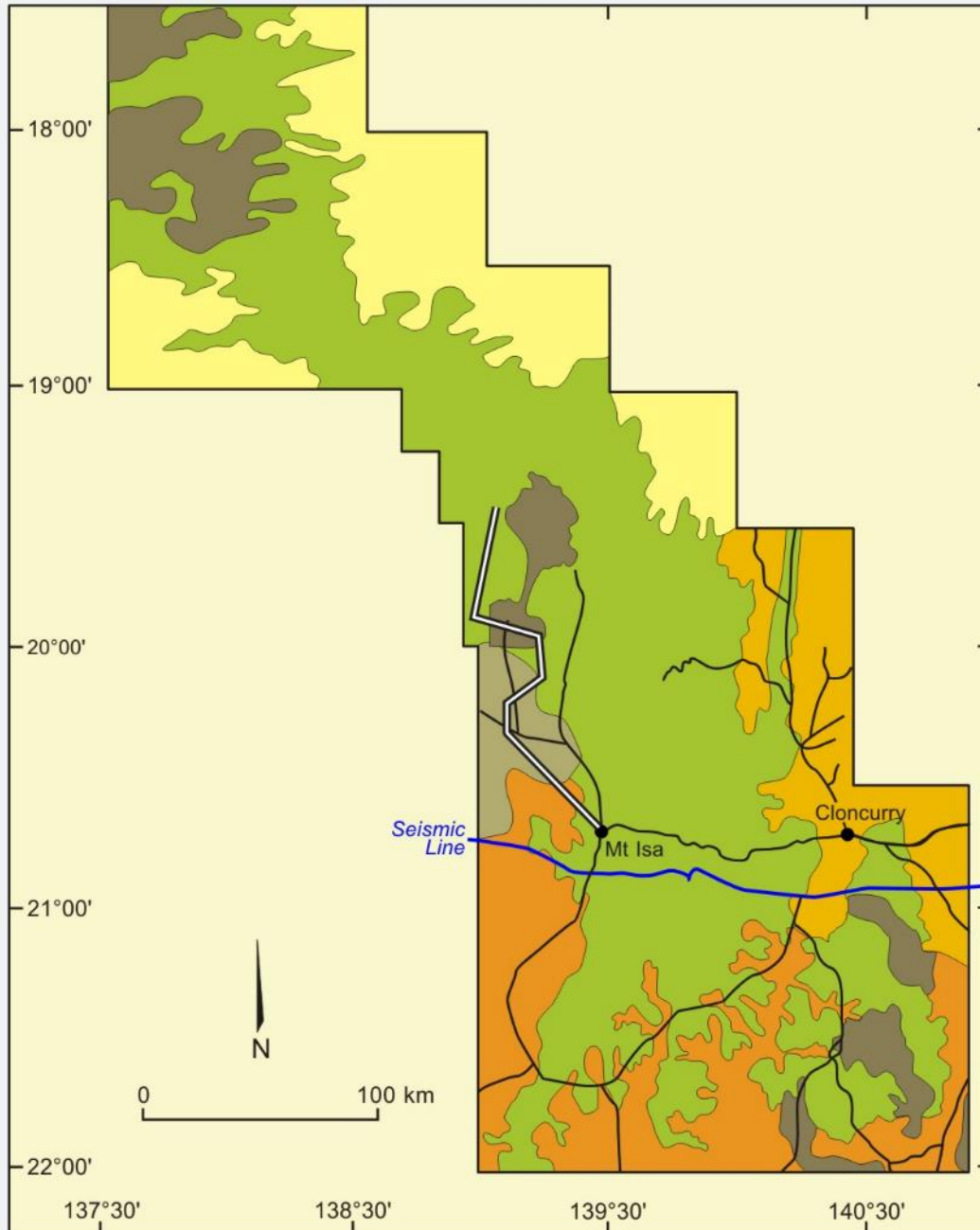
Aerial photo
regolith interp

Radiometrics
RGB = K, Th, U

Total magnetic
intensity

Cornelius and
Wildman 2000

Geomorphological Provinces - Mt Isa Region



 Hill belts

Plains

 Gently sloping

 Undulating to rolling

 Flat

Dissected palaeosurface

 Largely on Proterozoic basement

 Largely on Mesozoic sediments

 Transect

 Major roads

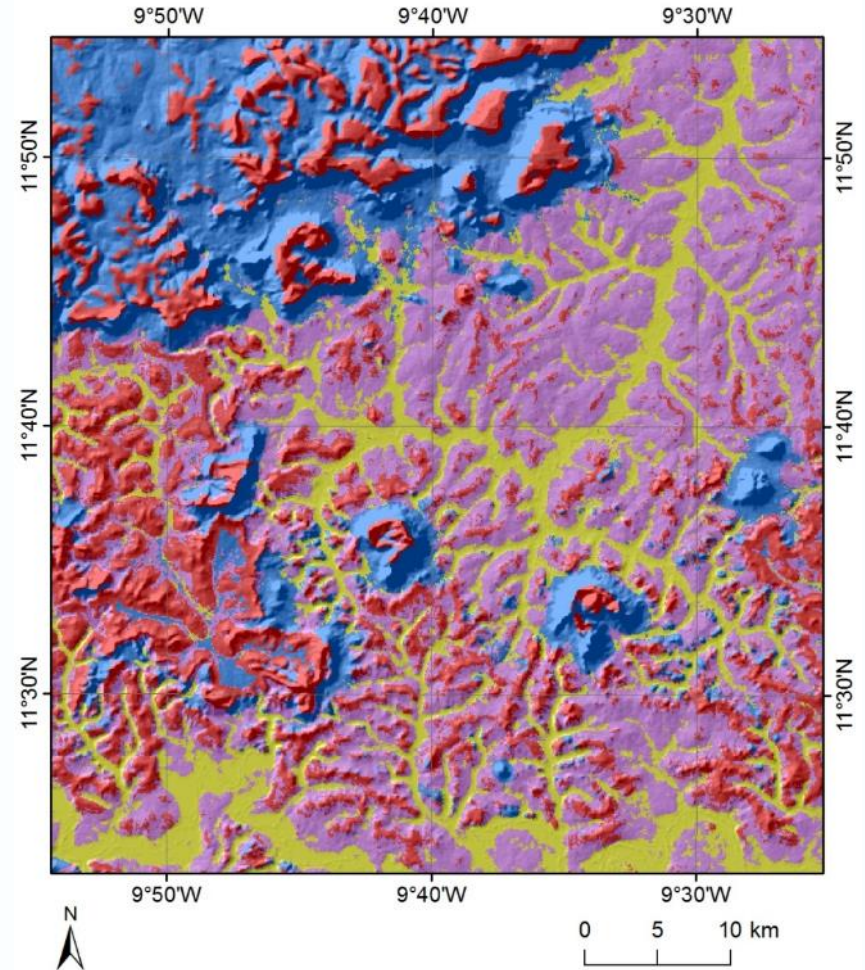
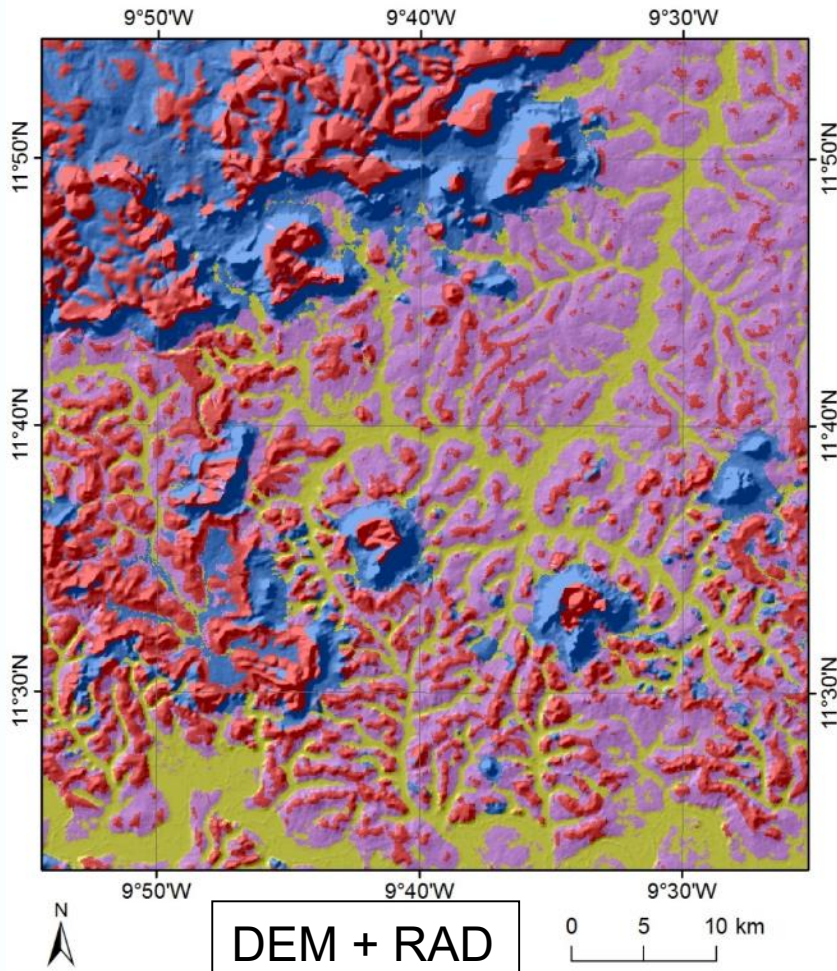
Anand, 2016



CRCLEME

Data science in regolith mapping

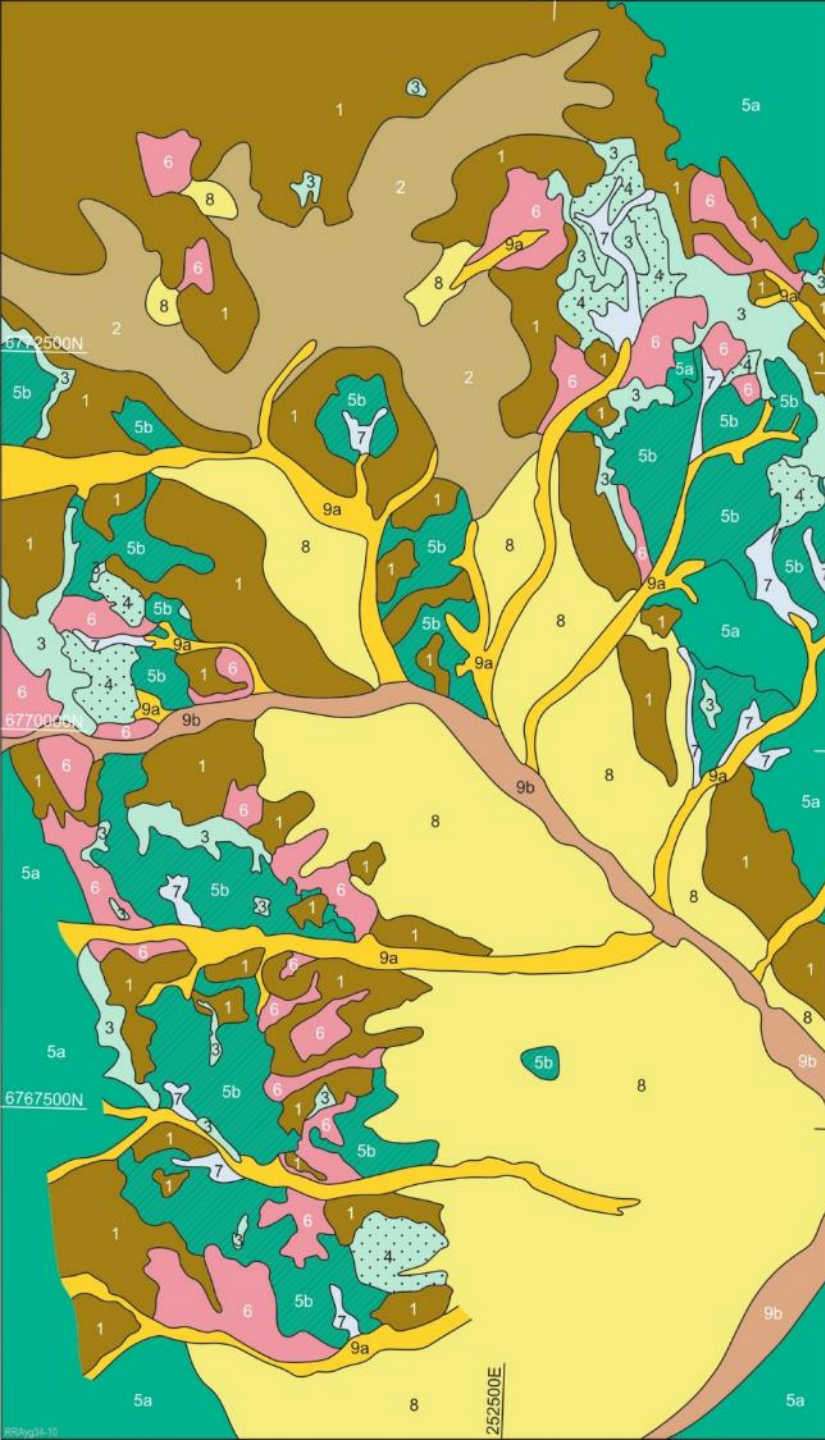
Input bands	O.A. (%)	K
DEM+RAD	89.67	0.86
DEM+RAD+L7	92.87	0.90



DEM + RAD + Landsat 7 ETM+

- Fe-rich duricrusts
- Lower Glacis (partially indurated)
- rock outcrop/suboutcrop
- alluvial sediments

Factual regolith-landform map

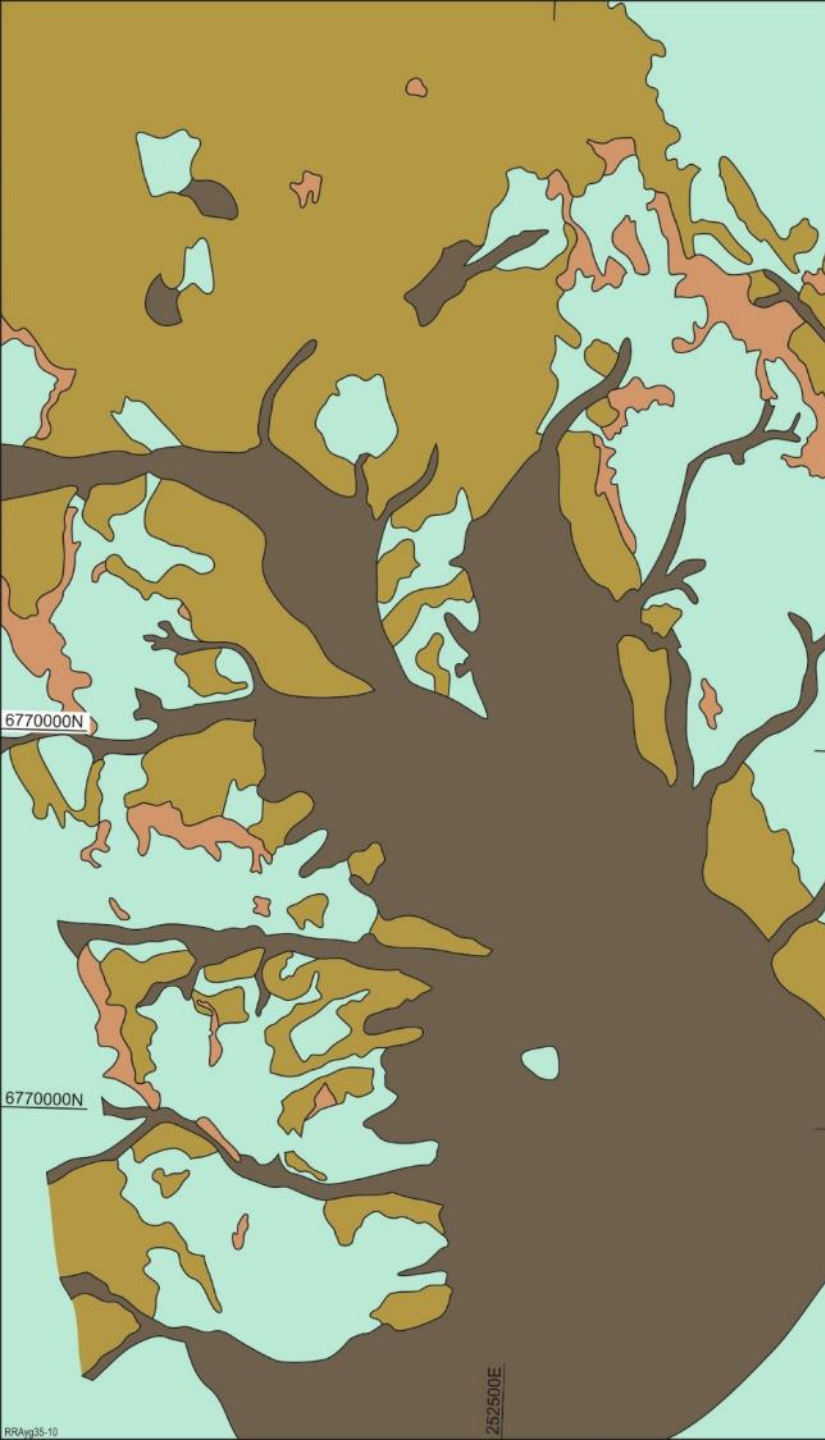


	Mapping unit	Abbreviated characteristics
Ferruginous gravel and duricrust	1	Crests and slopes; Fe-duricrust; yellow-brown nodules and pisoliths; gossaneous ironstones; acid, gravelly sandy loam
	2	Local valley floors and lower slopes; dark brown to black nodules and pisoliths; acid, gravelly, fine, sandy loam; substrate of pisolitic-nodular lateritic residuum
Saprolite and bedrock	3	Steeply sloping, breakaway faces; pale saprolite outcrops; very thin stoney calcareous earths
	4	Steeply concave pediments; saprolite; calcareous earths
	5a	Low hills, saprock; calcareous earths, shallow acid earths
	5b	Low rises, saprock; calcareous earths
Sediments	6	Gently concave pediments with pedisediment, acid red earths
	7	Minor calcareous alluvial tracts
	8	Alluvial plains; polymictic lag; acid, red earths
	9a	Alluvium, minor tributaries; silty to sandy loam
	9b	Alluvium, medium-sized tributaries, silty to sandy loam

RRAy34L-10

Anand and Butt 2010

Interpretative regolith-landform map (Sampling strategy map)



Regime

Sample

Relict



Lateritic duricrust and/or gravel



Ferruginous lag & saprolite

Erosional



Soil – note colluvial & aeolian input)

Depositional

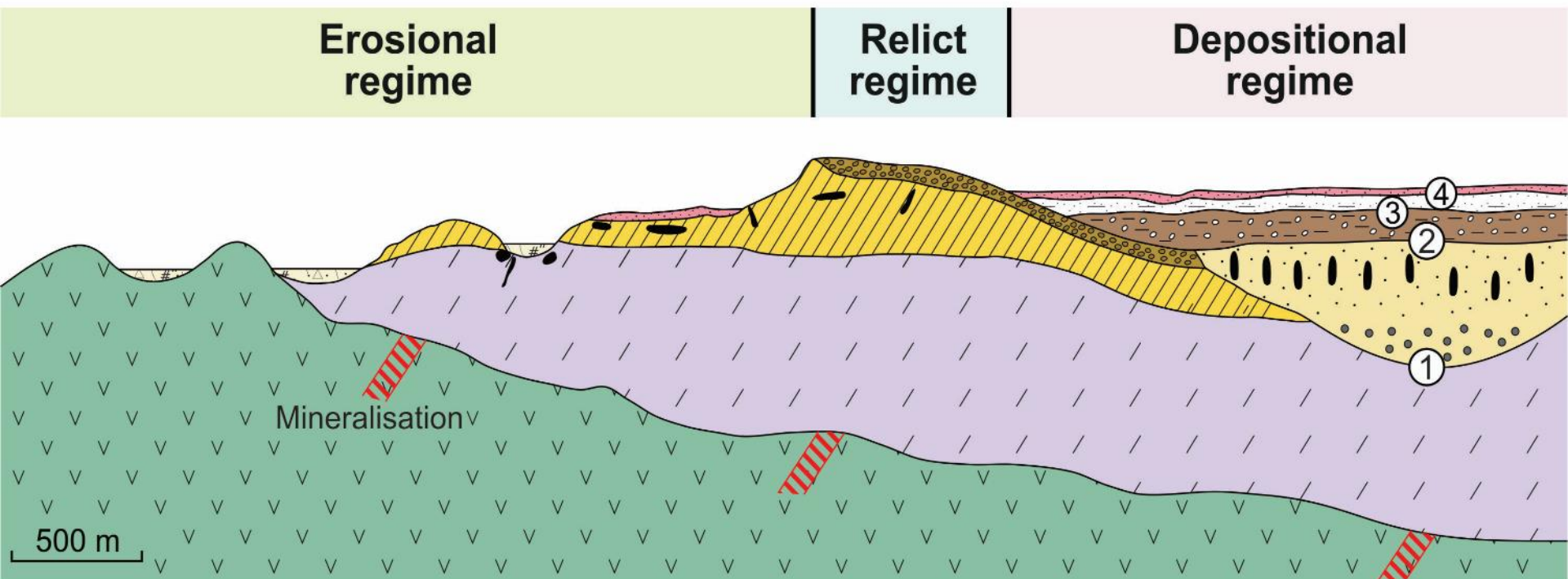



*Establish depth of overburden
nature of residual profile:*

Buried lateritic residuum preferred if present

Anand and Butt 2010

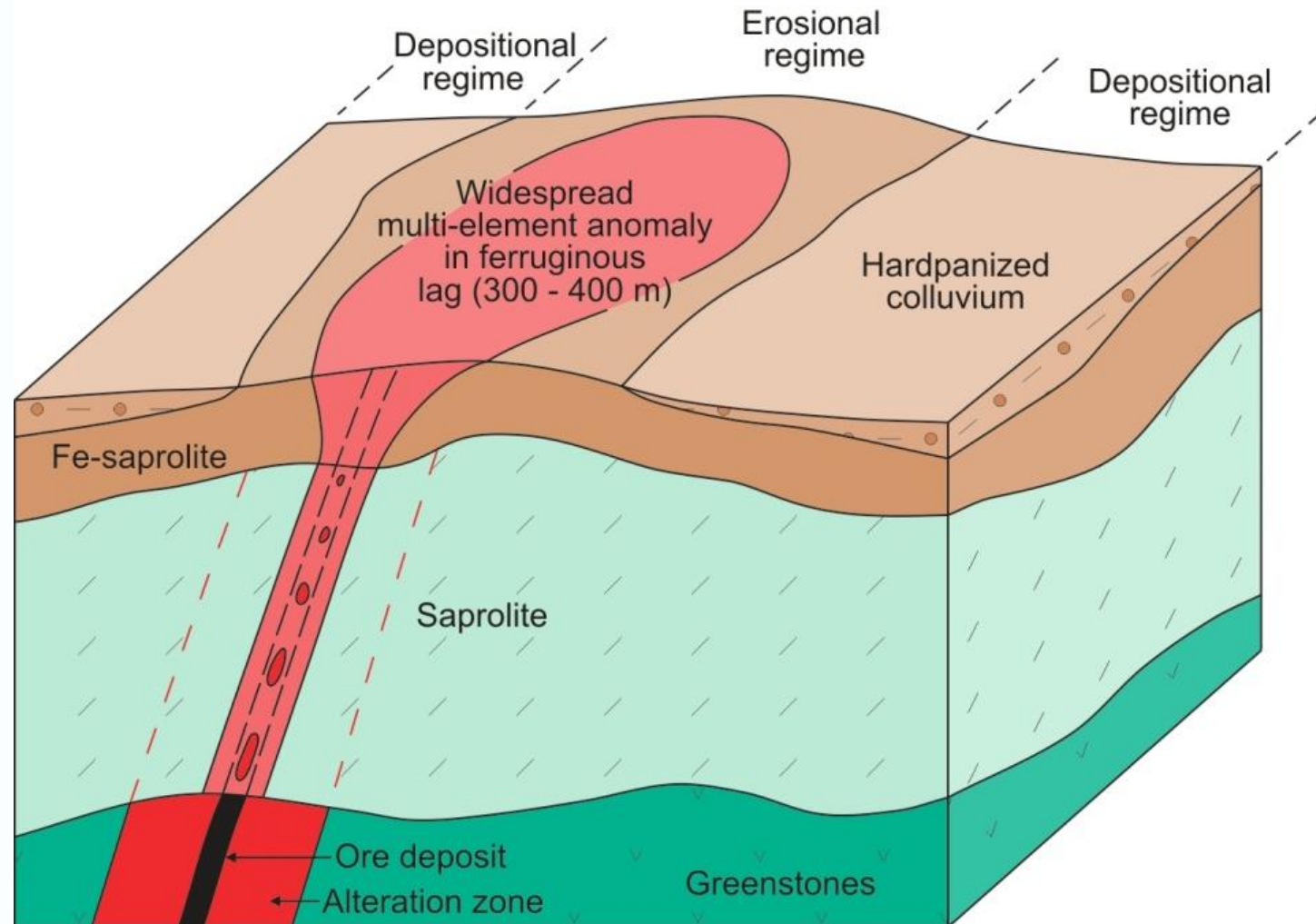
Exploration in residual terrains



- | | | | |
|---|--|---|-------------------------------|
|  | Acid red sandy soil |  | Lateritic residuum |
|  | Sandy clay |  | Mottled/ferruginous saprolite |
|  | Silicified (hardpanised) sandy silty clay |  | Iron segregations |
|  | Hardpanised gravelly sandy clay |  | Saprolite |
|  | Red, megamottled or bleached palaeochannel clays |  | Bedrock |
|  | Concentric pisoliths |  | Interfaces |

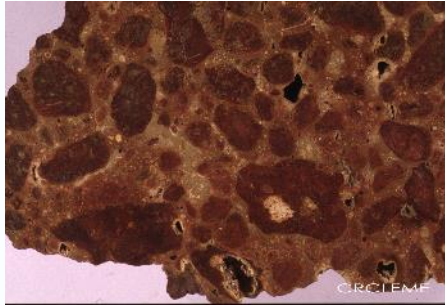
Geochemical model for residual soil and lag on saprolite (erosional regime)

Residual and chemical dispersion



Dispersion model for exposed lateritic residuum

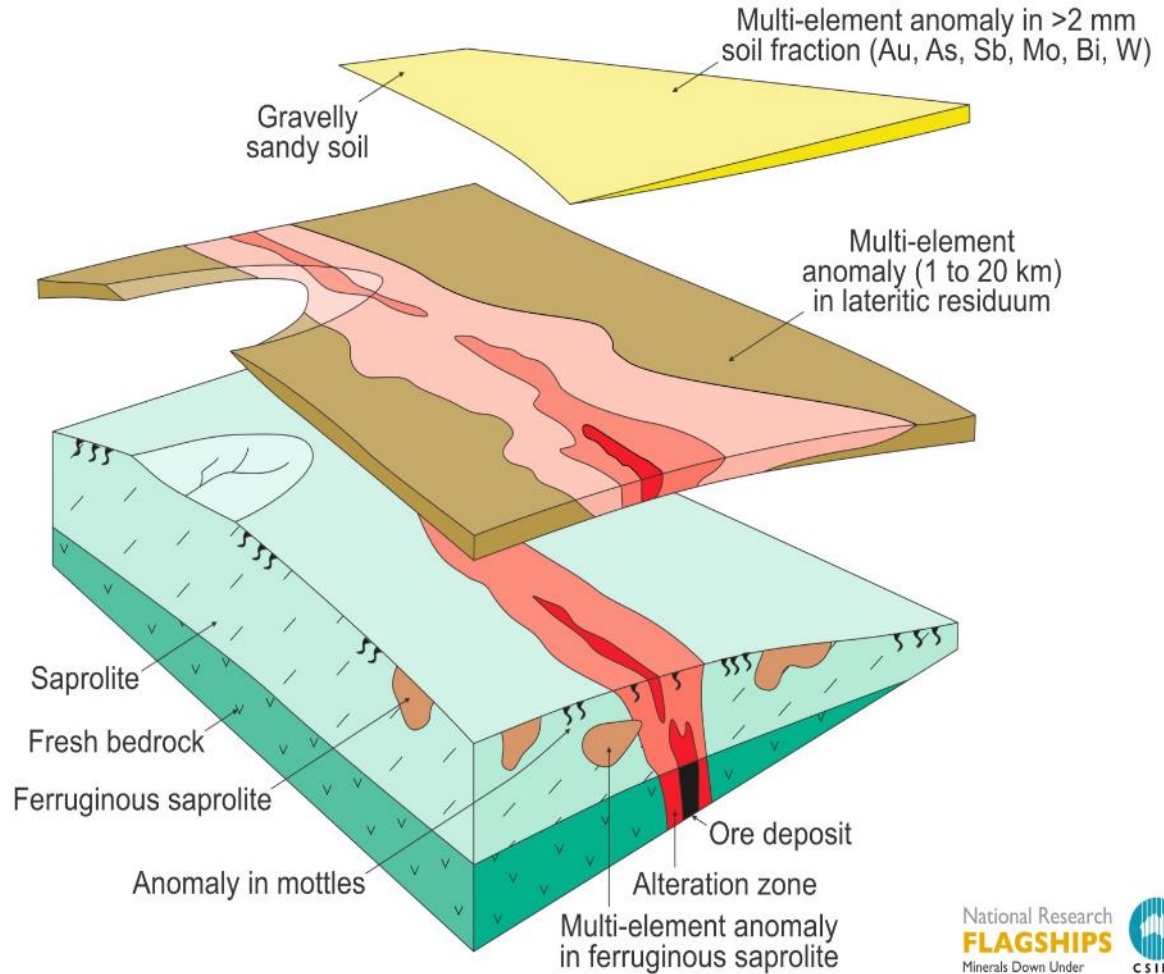
Lateritic residuum



Saprolite



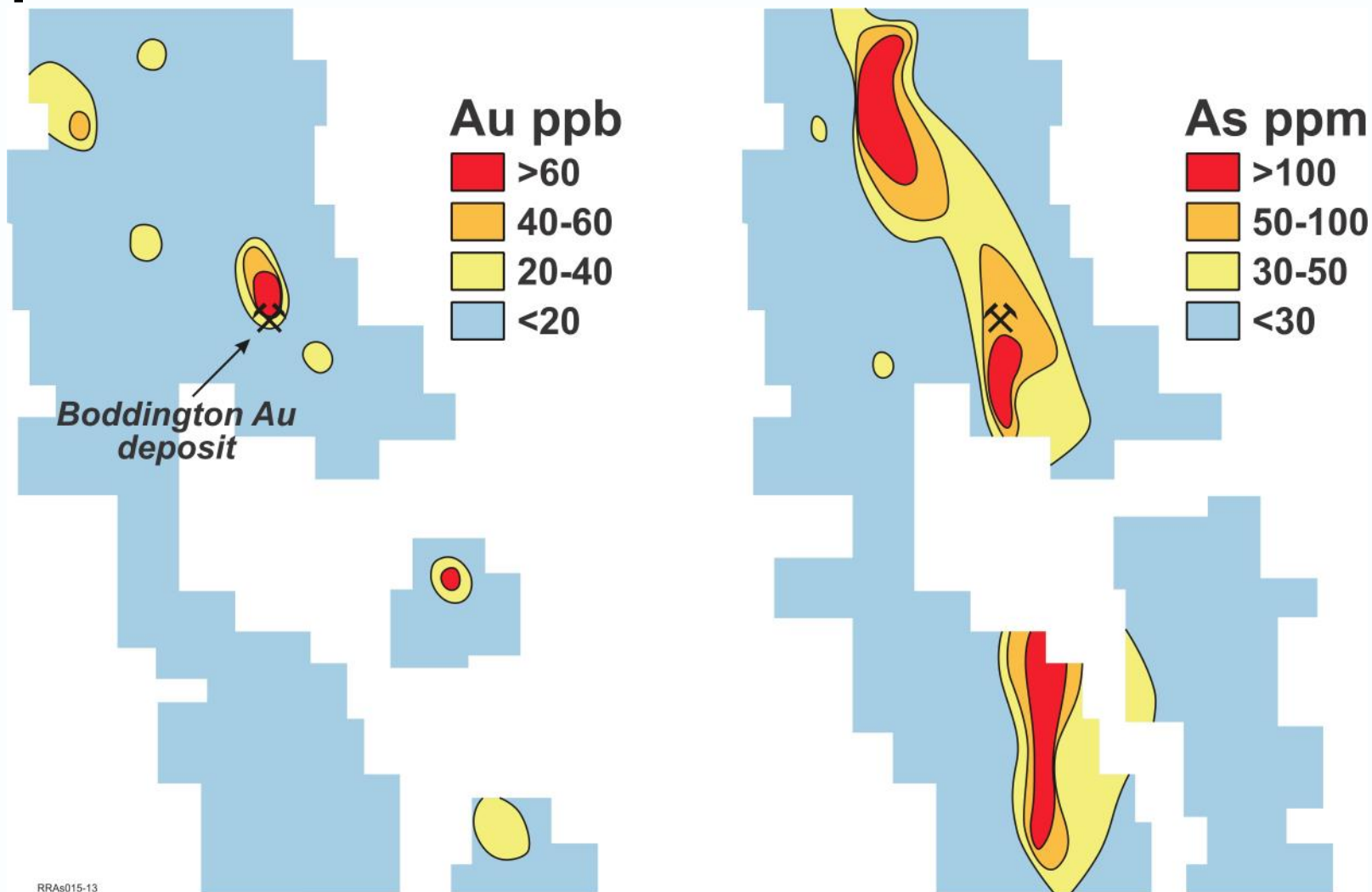
Bedrock



Geochemical haloes in lateritic residuum can be up to 10-100 times more than ore body

Smith and Anand, 1992

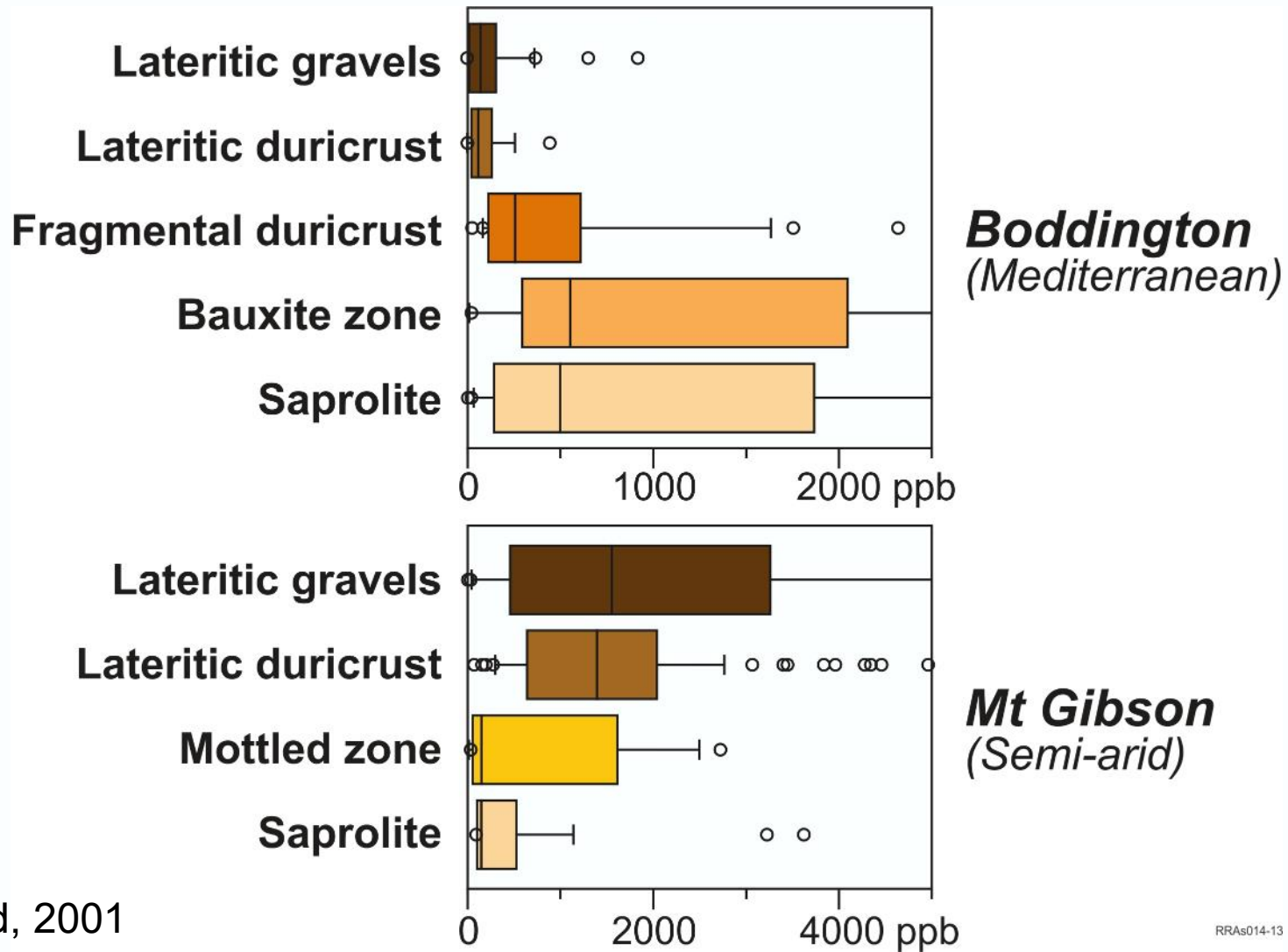
Anomaly in lateritic residuum, Boddington Au deposit



RRAs015-13

RE Smith

Comparison of Au distribution



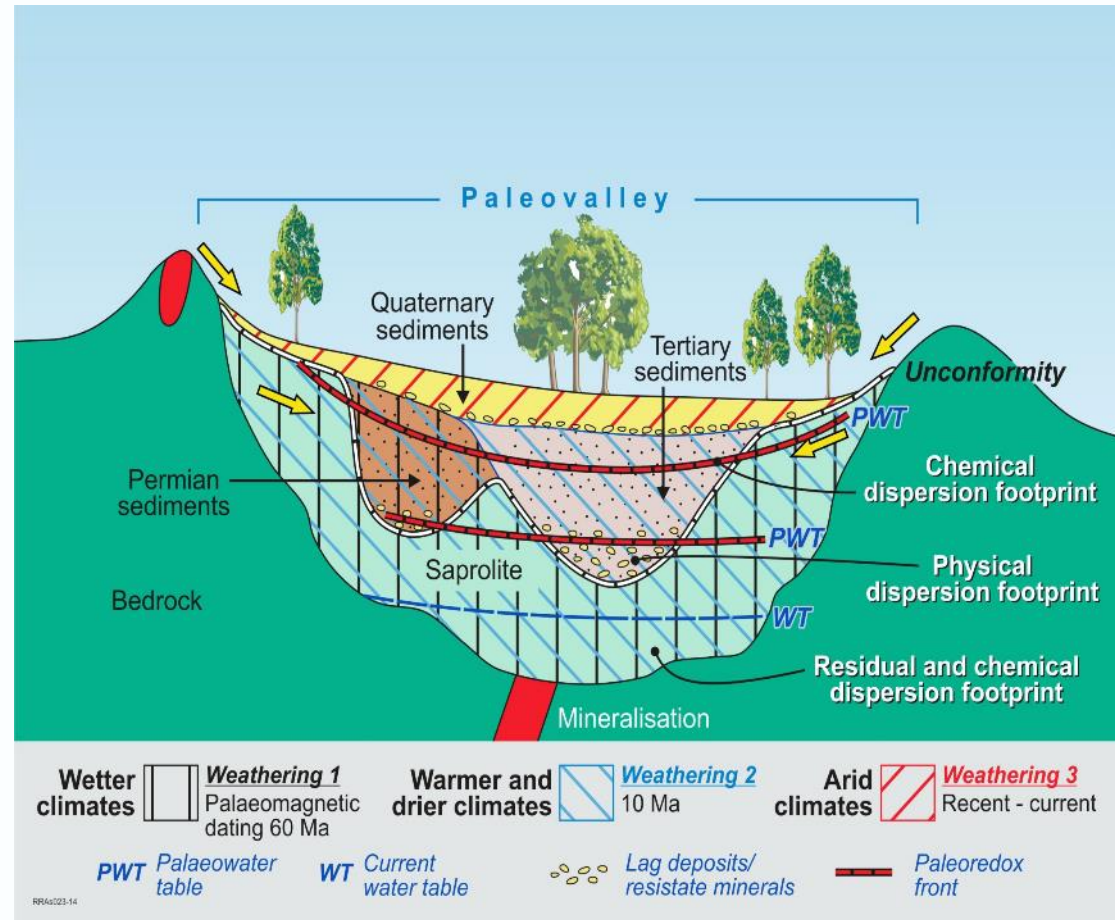
Anand, 2001

RRAs014-13

What we do in areas of deep cover where surface techniques don't work?

Need to understand:

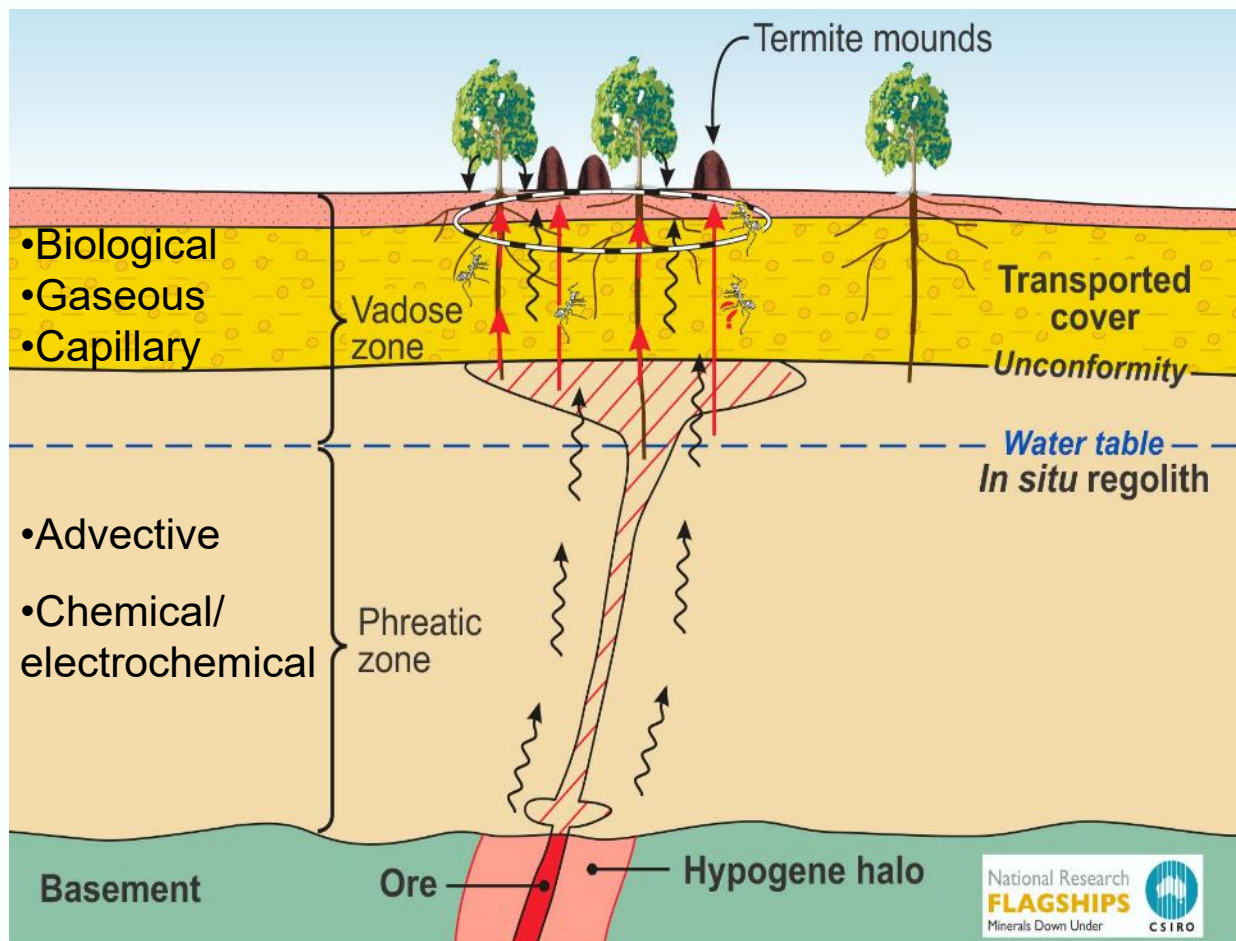
- Geochemical and mechanical dispersion in cover sequences (e.g., physical and chemical interfaces)
- Mapping of architecture and important interfaces using geophysics



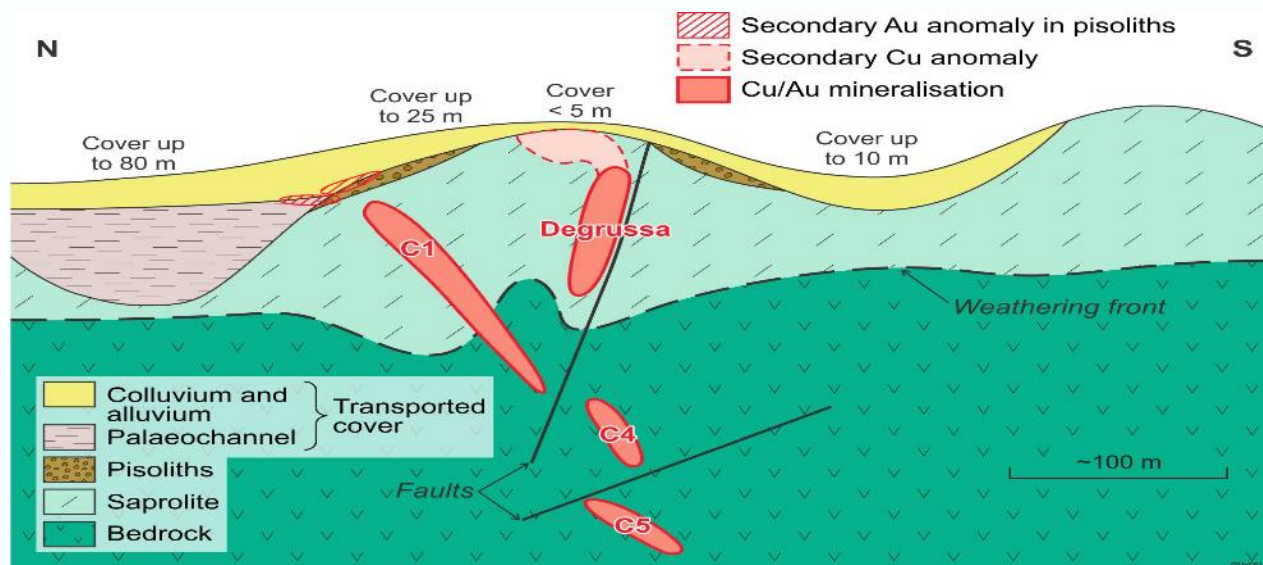
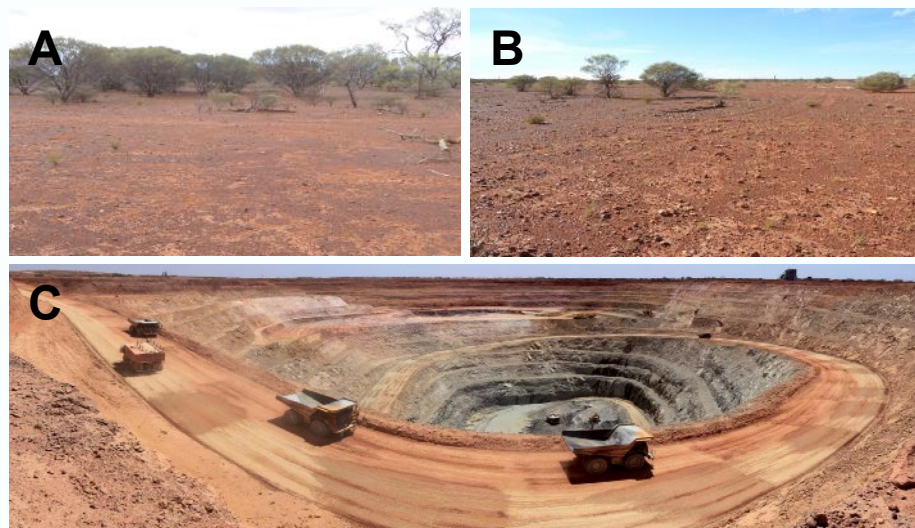
Dispersion mechanisms that can move metals from mineralisation through transported cover to surface

Mechanisms can be grouped based on whether they are within saturated groundwater (**phreatic zone**) or above the saturated zone (**vadose zone**)

Phreatic zone processes involving groundwater flow, dilatancy, bubbles, diffusion and electrical migration and **vadose zone** processes involving capillary migration, gaseous transport and biological transfer

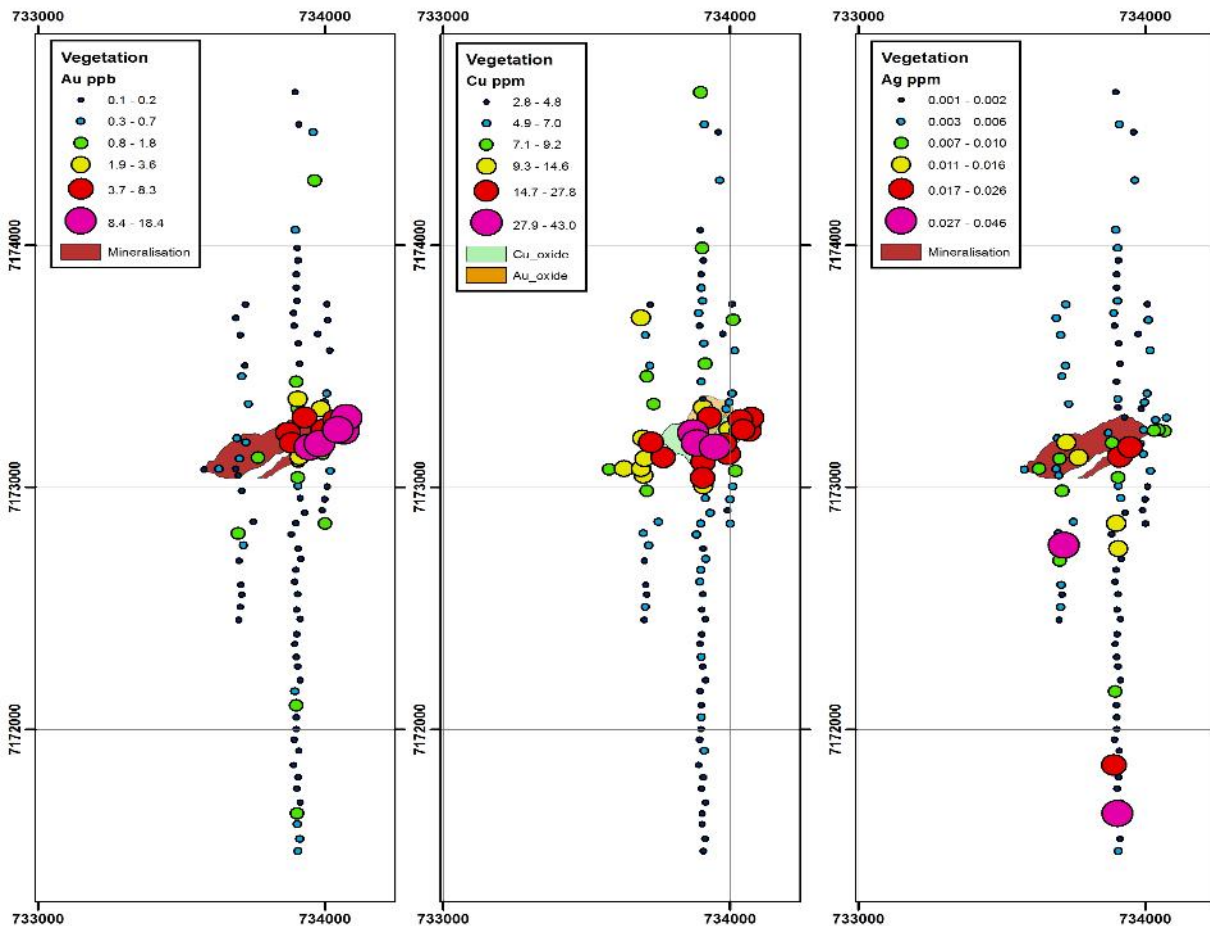


Vegetation mechanism: DeGrussa Cu-Au deposit



Noble and Anand

Dispersion mechanism: **Vegetation:** Multi-element anomaly (Pb, Sb, Te) in *Acacia aneura* (Mulga), DeGrussa Cu-Au deposit



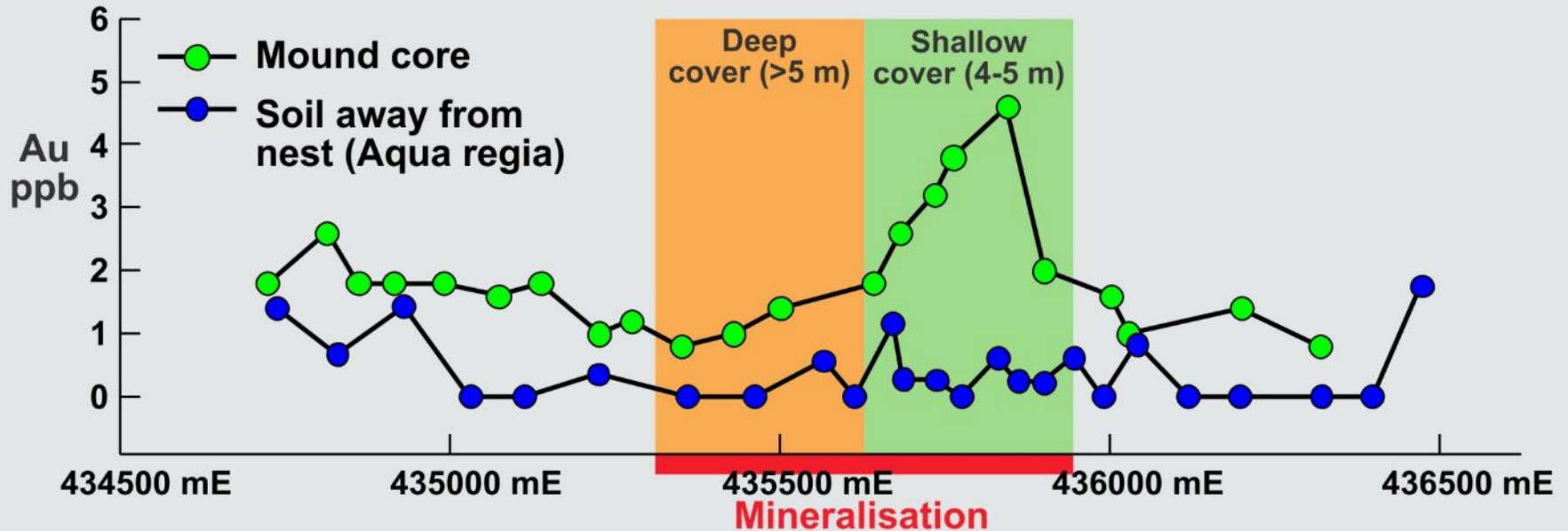
- **5-20 m of cover**
- **Supergene mineralisation in saprolite**
- **Au, Cu, As, Bi, Pb, Sb, Se anomaly in vegetation**



Noble, Anand, Gray, Cleverley 2017

Dispersion mechanism: **Termites**

Moolart Well Au Deposit, Yilgarn Craton









- 5-15 m of transported cover
- Response in termite mounds but not in soil using aqua regia or partial extractions
- Response in termite mounds in shallow cover only

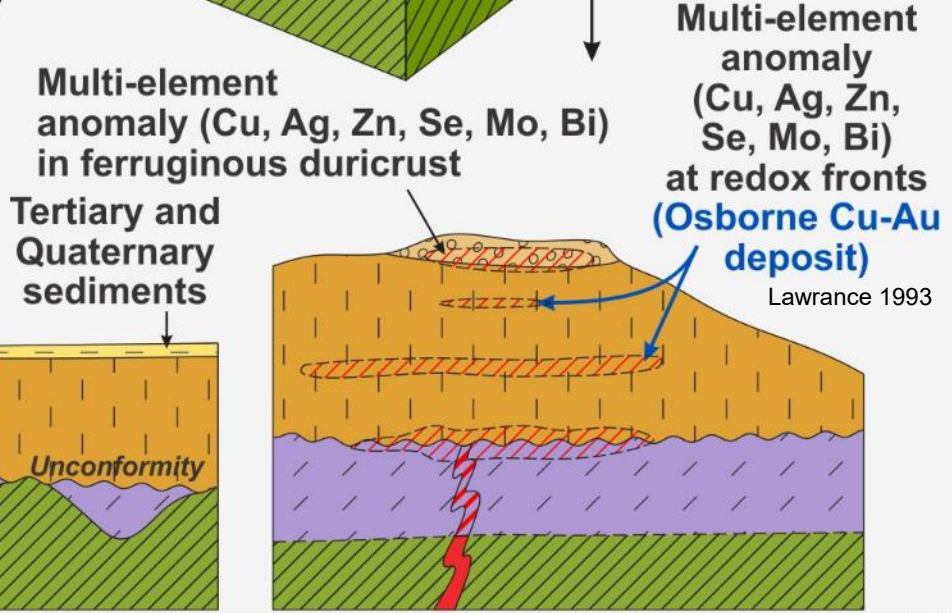
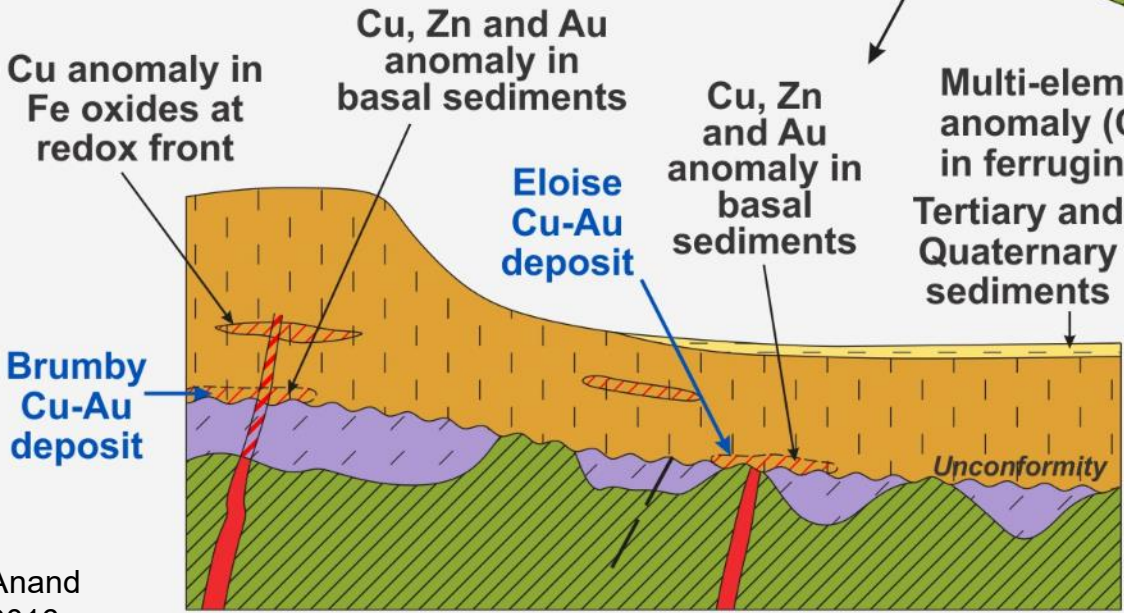
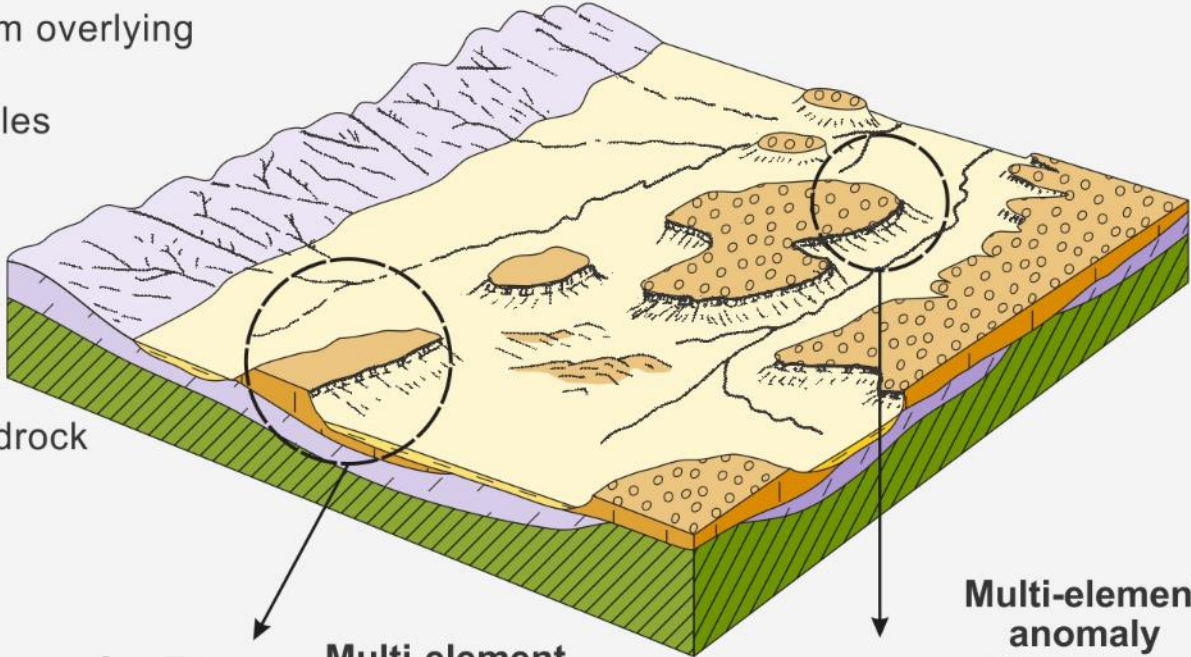
Stewart and Anand 2012



Tumulitermes tumuli

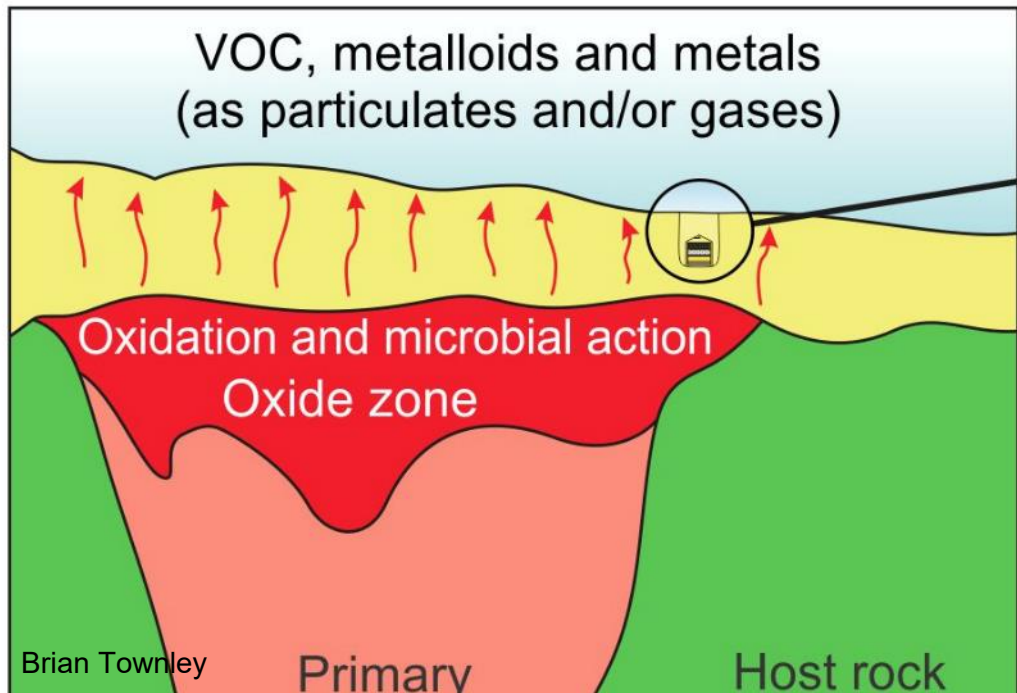
Cover geochemistry: Interfaces and paleoredox fronts anomalies in areas of deep cover, Mt Isa region

-  Soils, colluvium and alluvium overlying saprolite or saprock
-  Ferruginous duricrust, nodules and pisoliths, silcrete
-  Saprolite
-  Ferruginous and silicified saprolite
-  Saprolite on Mesozoic sediments
-  Saprolite on Proterozoic bedrock
-  Proterozoic bedrock



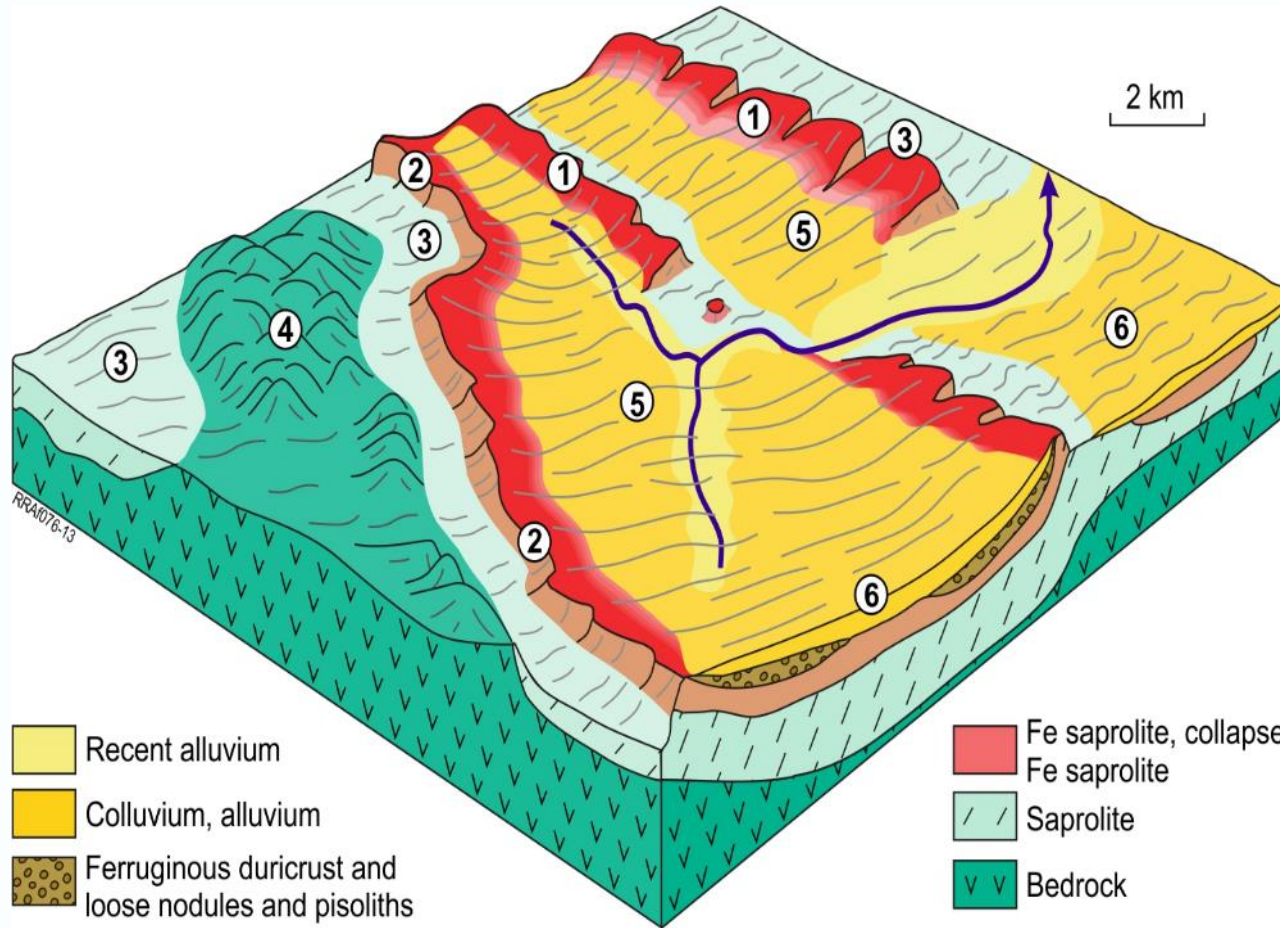
Lawrance 1993

Dispersion mechanism: **Gaseous**: Theoretical basis for gaseous/hydrocarbon transfer



- Soil gases offer a good potential mechanism for metal migration because of their high mobility through transported cover
- Gases are not as limited by the distance of vertical dispersion as is biogeochemical cycling by tree root depth or water table depth
- Little application so far in mineral exploration
- Significant reduction in labs providing analytical service (a lack of transparency and evaluation)
- Showing some promising results

Implications to exploration: regolith, landforms and sample media



- ① Ferruginous duricrust, nodules, and pisoliths (establish origin)
- ② Fe saprolite; lag
- ③ Lag, soil, saprolite (identification of aeolian material critical)
- ④ Soil, fresh rock (identification of aeolian material critical)
- ⑤ Buried ferruginous duricrust and loose nodules and pisoliths (establish origin), Fe saprolite
- ⑥ A. Where transported overburden is <2 m thick - soil sampling (Northern region)
B. Where transported overburden is <10 m thick - calcareous soil sampling (Southern region) only for gold
C. Where transported overburden is >2 m thick - vegetation*
- termite mounds**
- interface
- buried saprolite
- groundwater

* only if cover is <20 m **only if cover is <5m

Thank you!

