Insights on the paradigms applied for mineral exploration in deeply weathered landscapes

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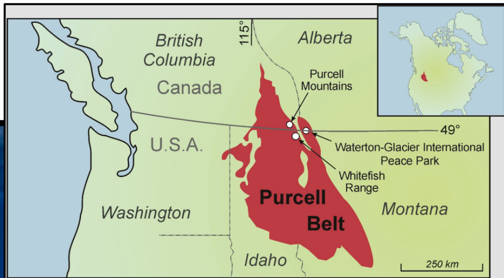
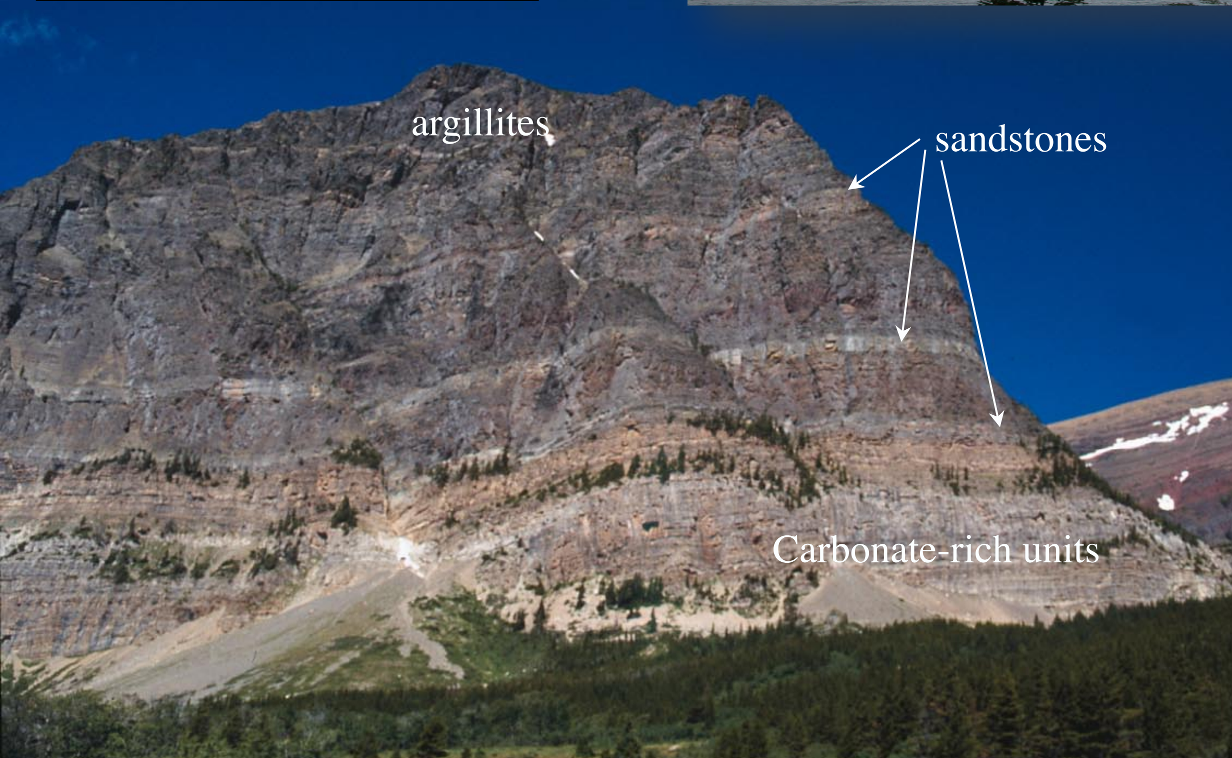
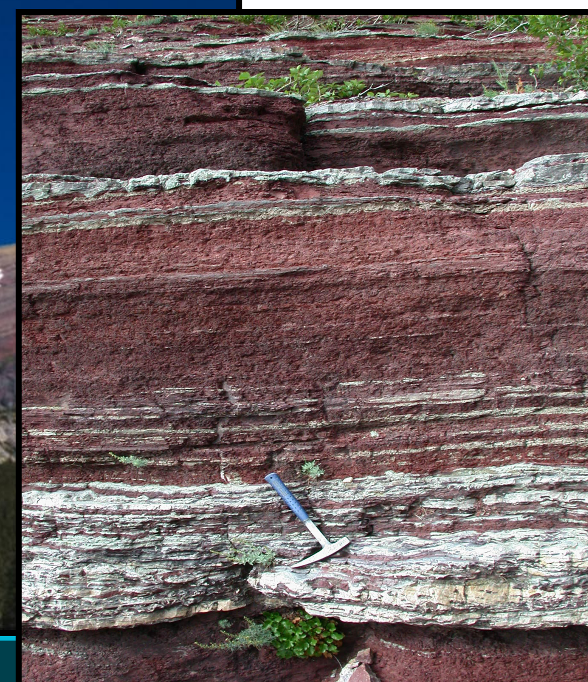
April 2018

Weathering, The Belt-Purcell Supergroup, A 1.5 Ga sedimentary sequence, 15 km thickness



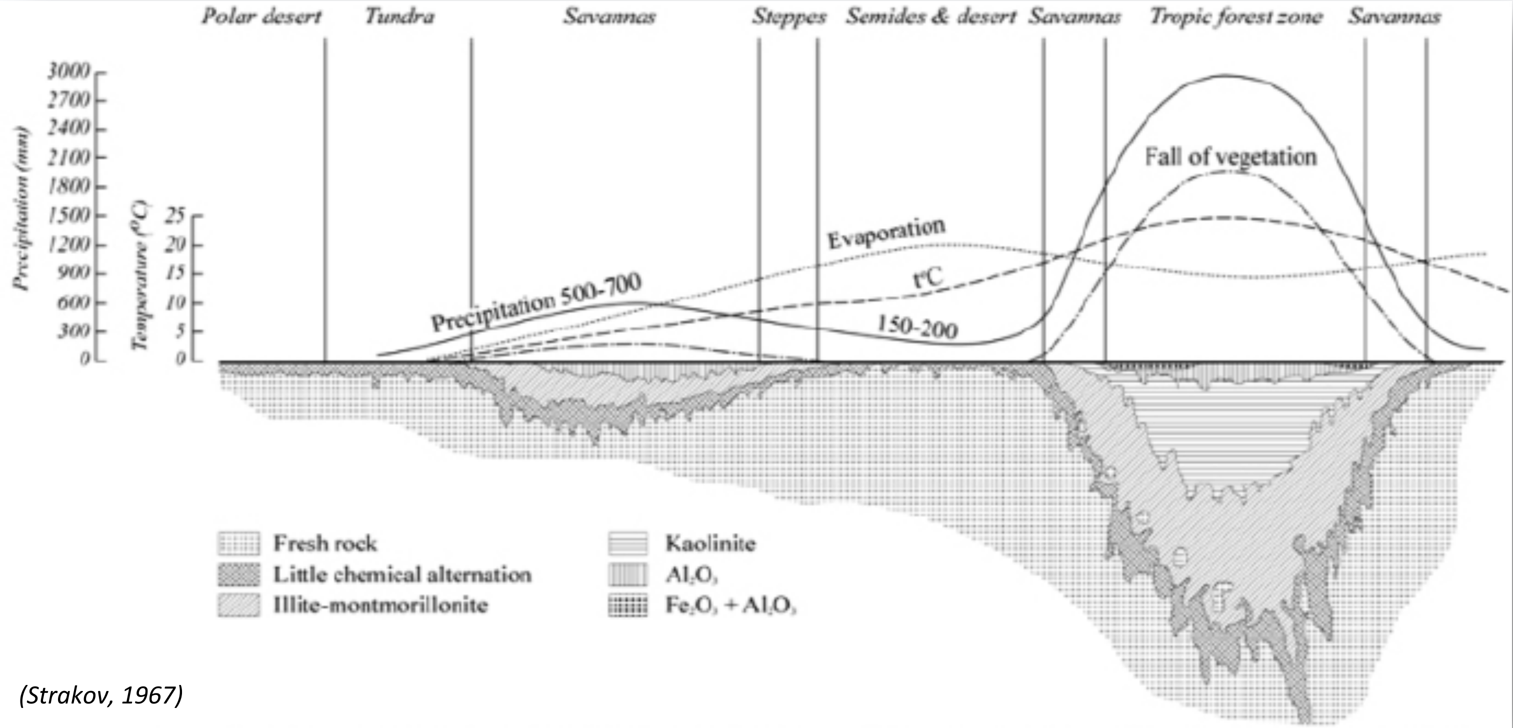




Weathering, the process

➢ (1) "The processes by which rock is broken into smaller pieces by the action of the weather".

(Cambridge specialized definition)



(Strakov, 1967)

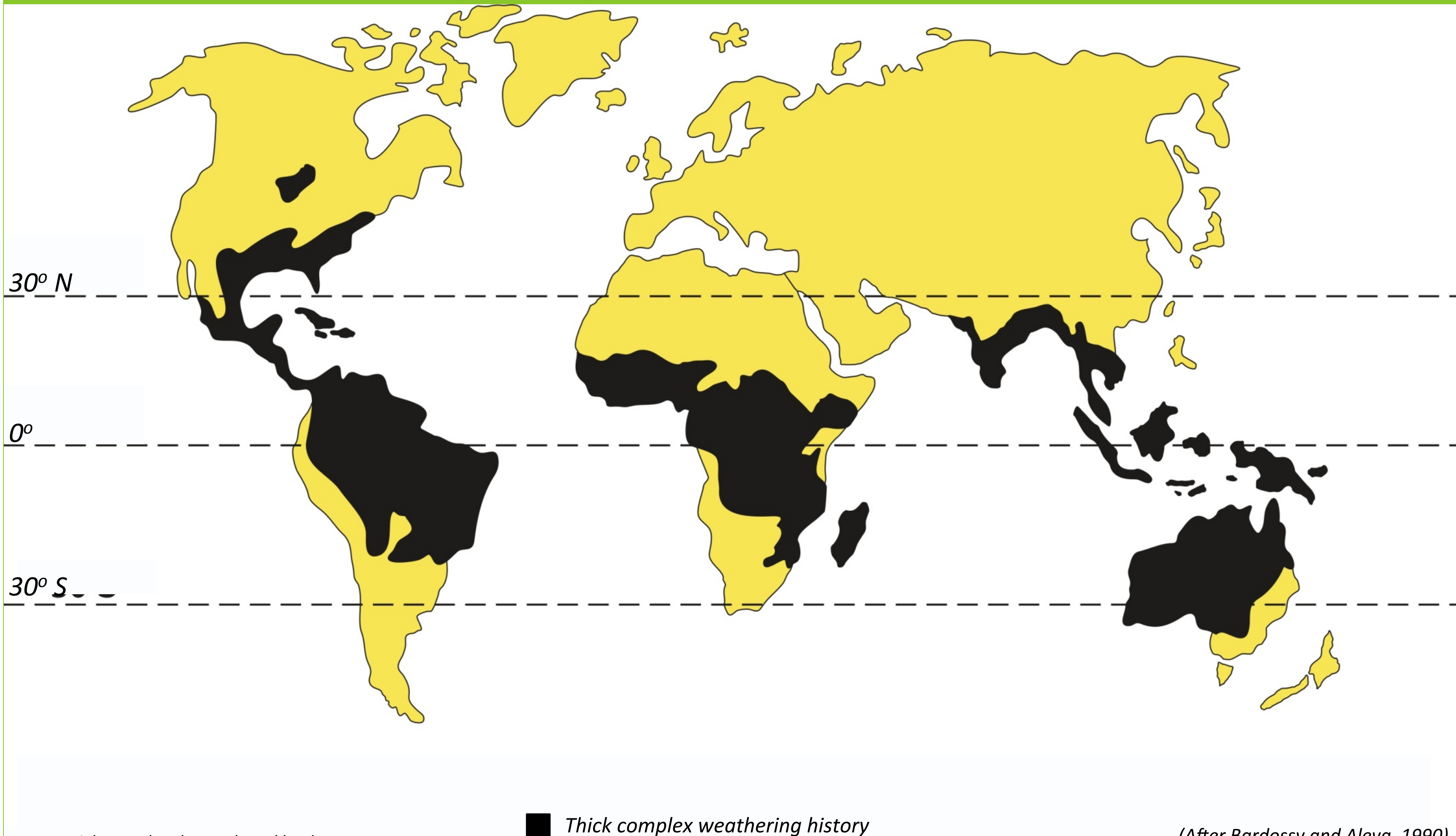
Regolith, the result of weathering

Regolith (Eggleton, 2001): "The entire unconsolidated or secondarily recemented cover that overlies coherent bedrock, that has been formed by weathering, erosion, transport and/or deposition of older material."

NE Albany-Fraser, WA

https://mars.nasa.gov/MPF/ops/rover_traverse_area.jpg

Distribution of deeply weathered regions; ~25% continental surface

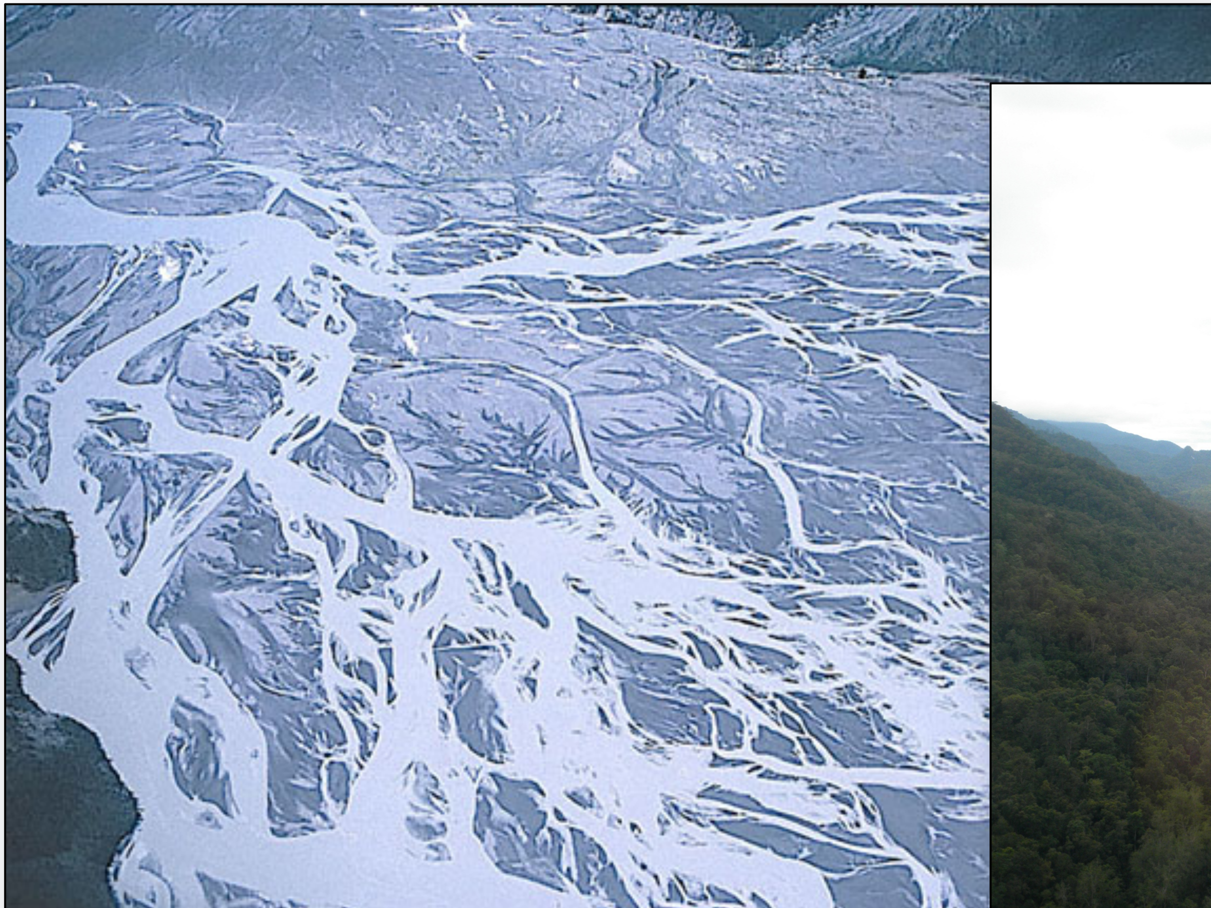


(After Bardossy and Aleva, 1990)

Distribution of sedimentary basins; >60%continental surface

• https://www.pinterest.com.au/pin/157485318193522392/

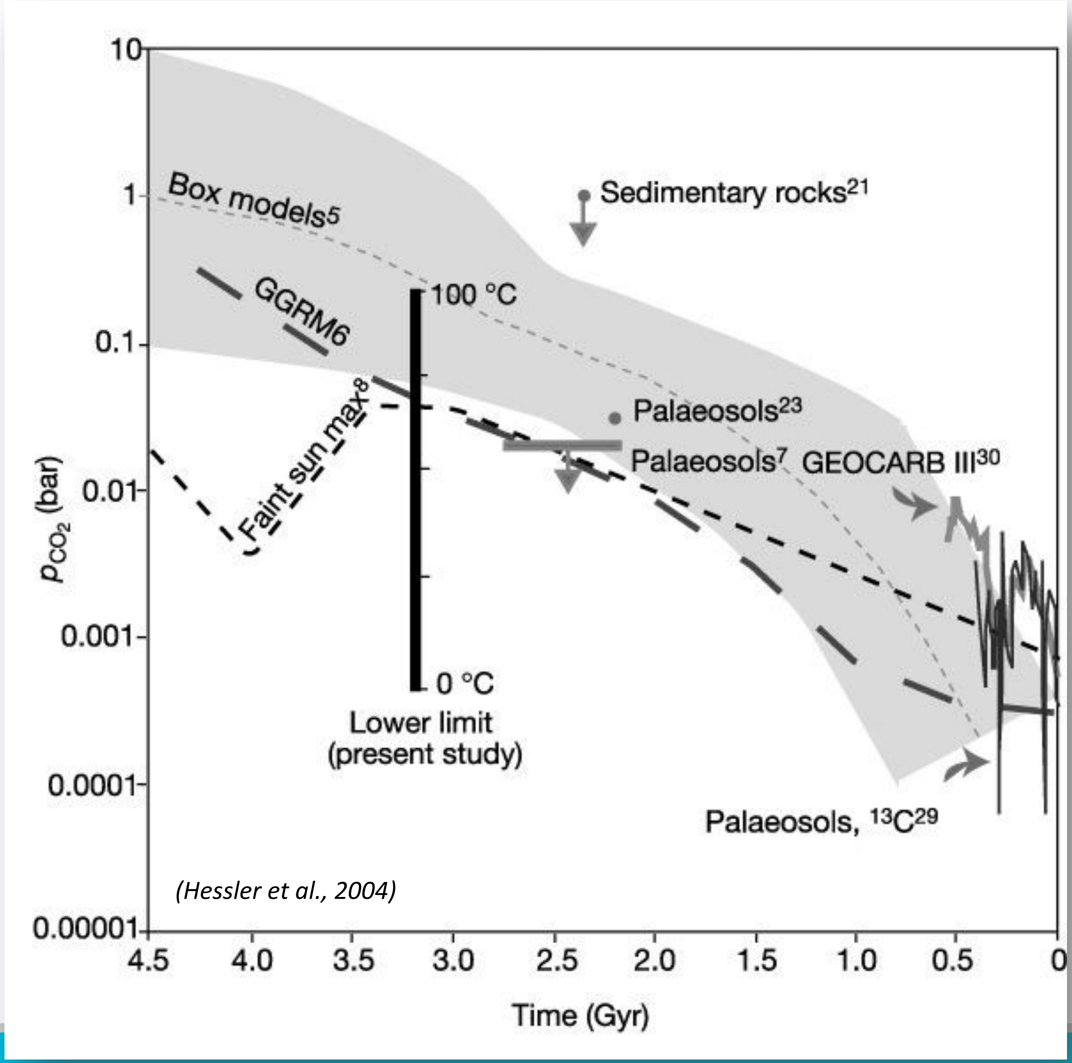
The cover spans all climatic conditions and geographical domains



(Slims river Yukon, Canada)

(SE Papua New Guinea)

Quantitative estimates of atmospheric CO_2 over geological time



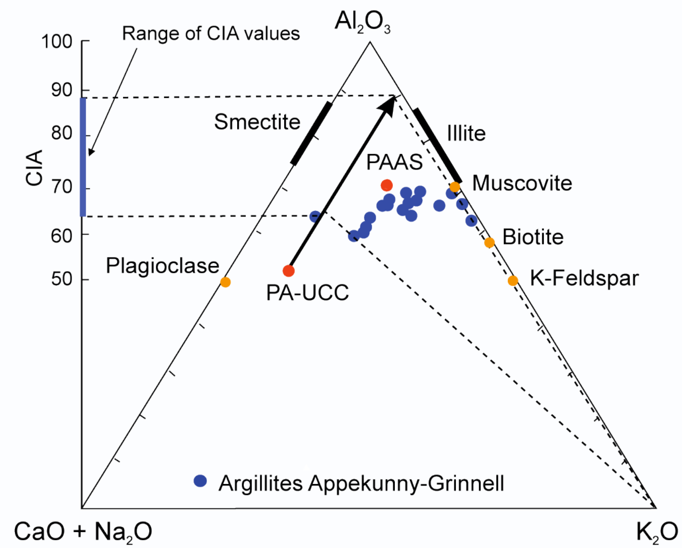
Chemical Index of Alteration

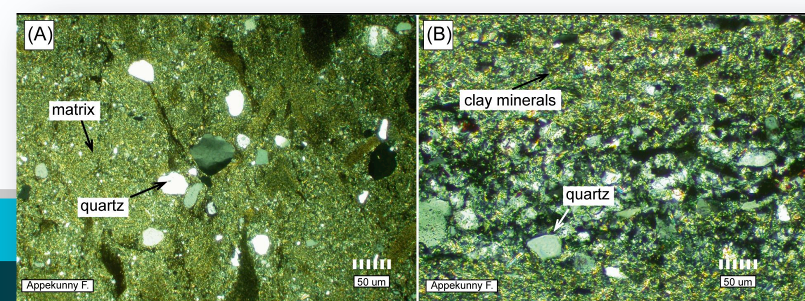
$$CIA = [Al_2O_3/(Al_2O_3 + CaO^* + Na_2O + K_2O)]/100$$

Reference values for chemical index of alteration, modified from Nesbitt and Young (1982).

	CIA
Fresh basalts	30-45
Fresh granites and granodiorites	45-55
Unaltered albite, anorthite and K-feldspar	50
Illite and montmorillonite	75-85
Kaolinite and chlorite	100
Archean Shield, NW Ontario, Canada	49
Upper Continental Crust (UCC)[2]	51
Pleistocene (last ~2.6 Ma) tills	~51
Pleistocene varved clays	~60
Pleistoce glacial clays	~65
Loess[1]	55-70
North American Shale Composite (NASC)[3]	68
Post-Archean Australian Shale (PAAS)[4]	70
Amazon cone muds	80-85
Residual clays	85-100

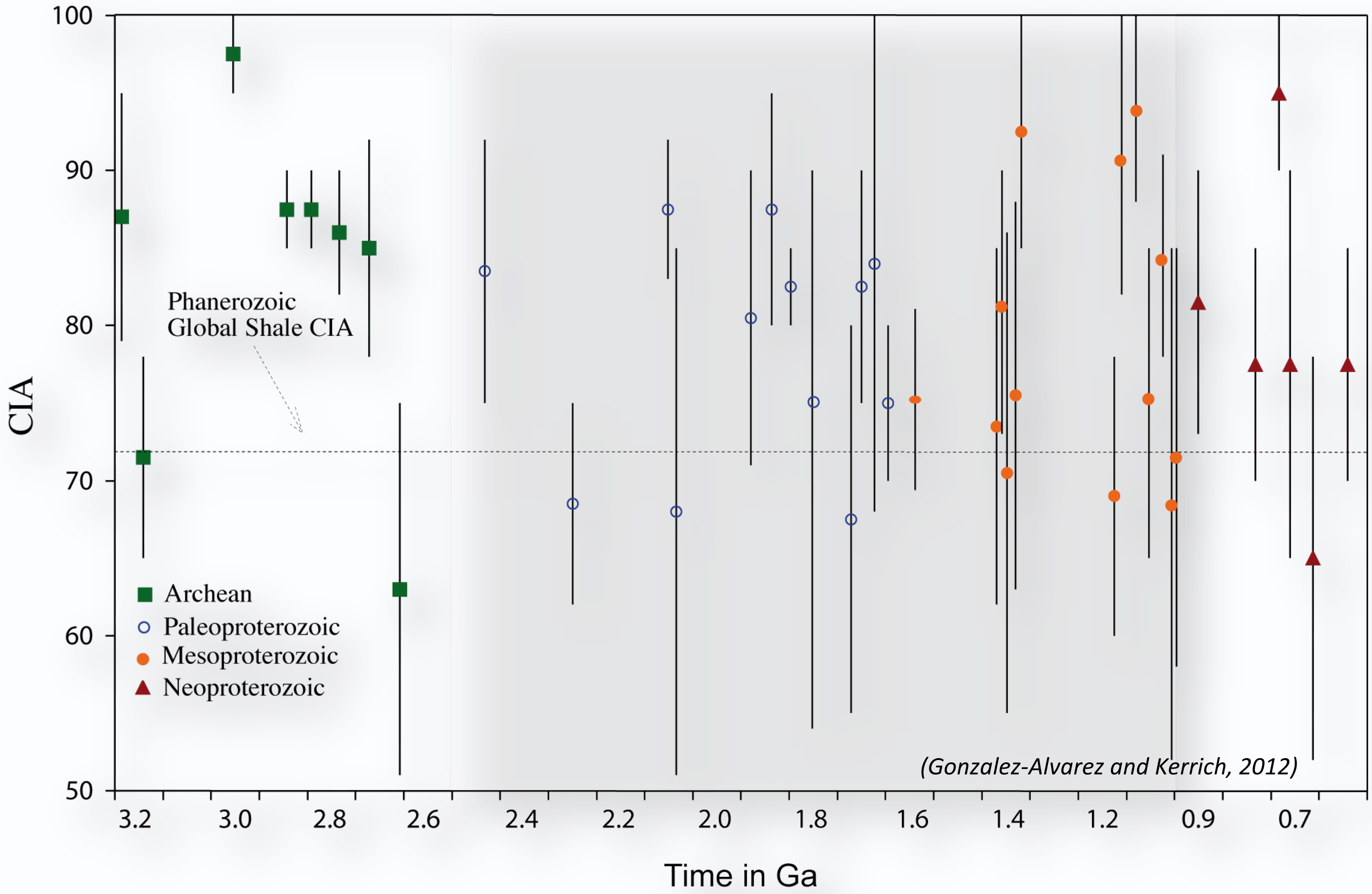
[1] Taylor and McLennan (1985); [2] Rudnick and Gao (2003); [3] Gromet et al. (1984); [4] Nance and Taylor (1976).



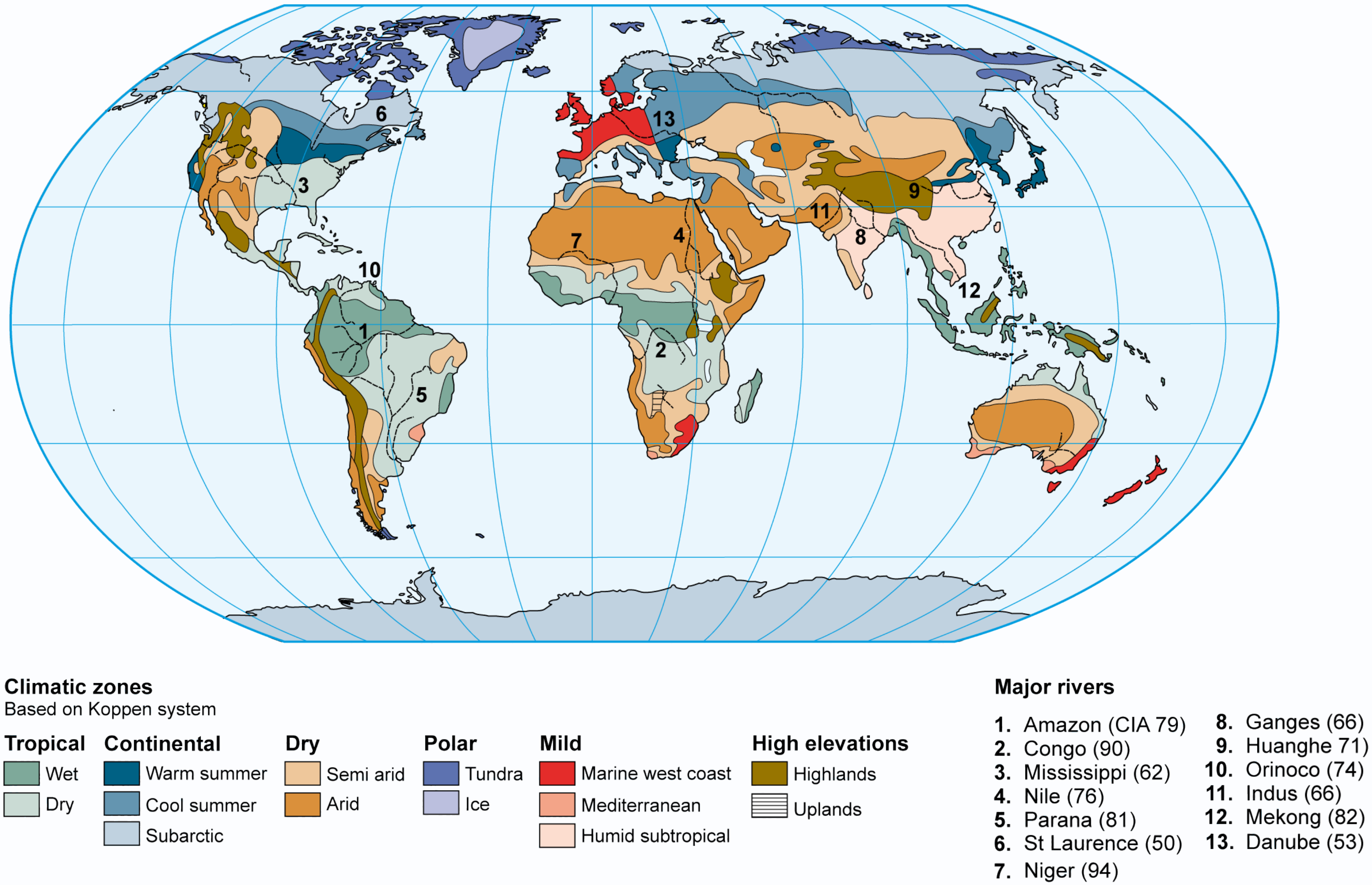


CIA Secular variations

38 sedimentary packages (world-wide, K corrected)



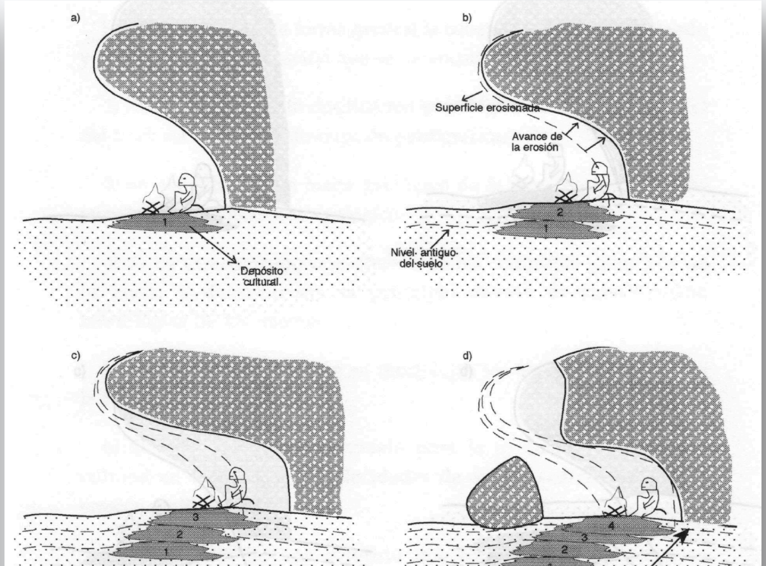
Climatic variability



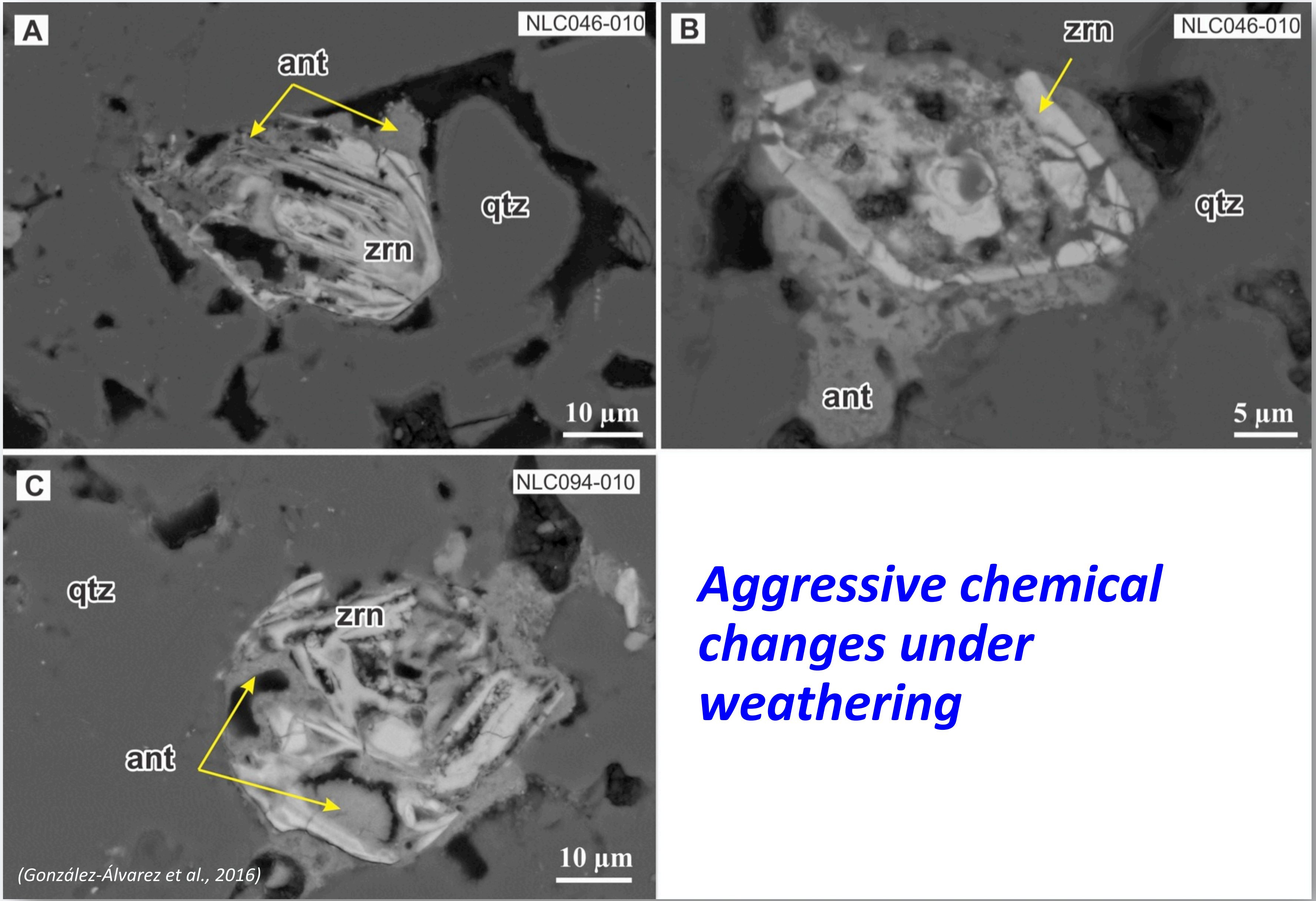
(Gonzalez-Alvarez and Kerrich, 2012)

Experiencing fast weathering

https://www.flickr.com/photos/72362673@N00/9957830505



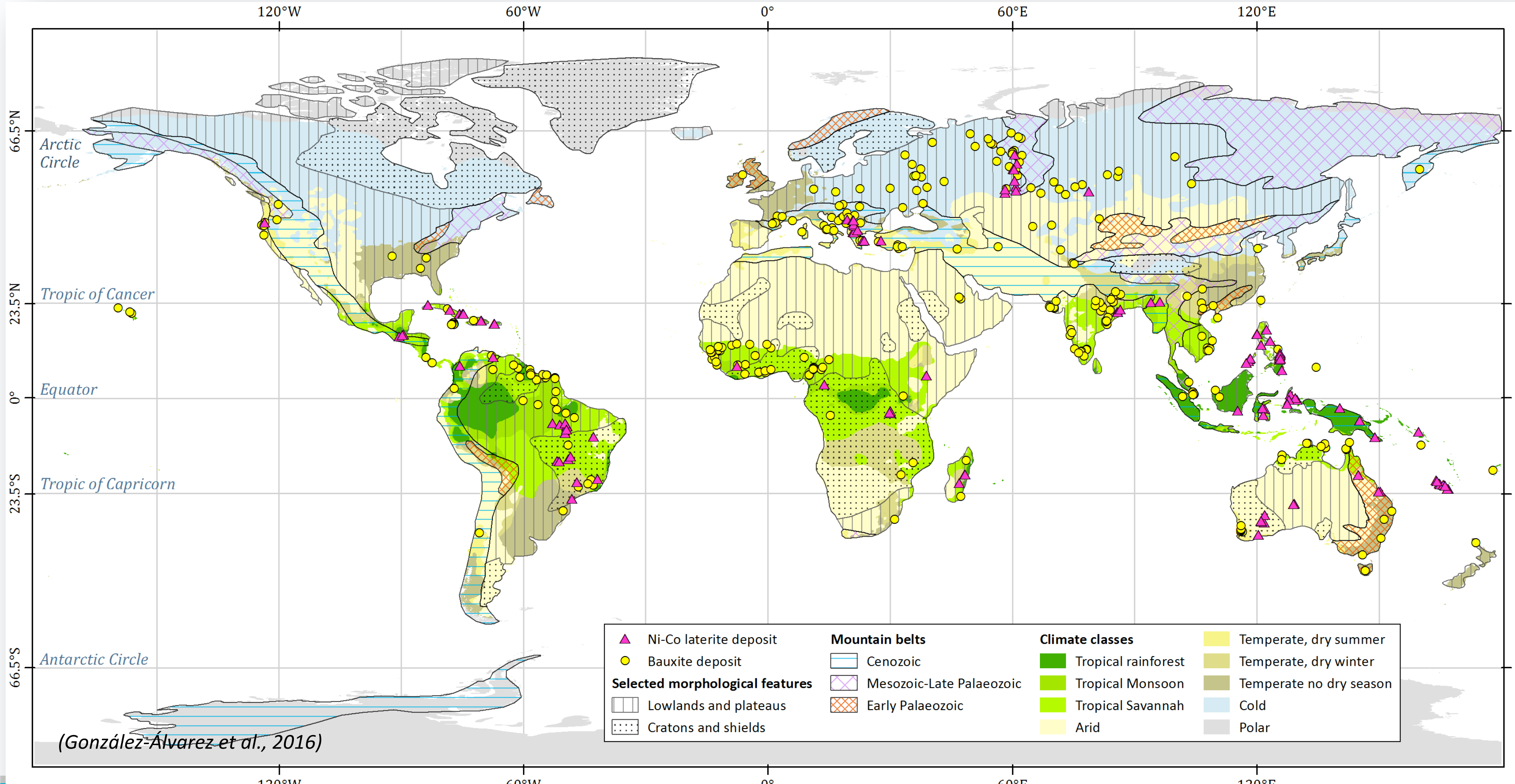
(Mercader et al., 2001)



(González-Álvarez et al., 2016)

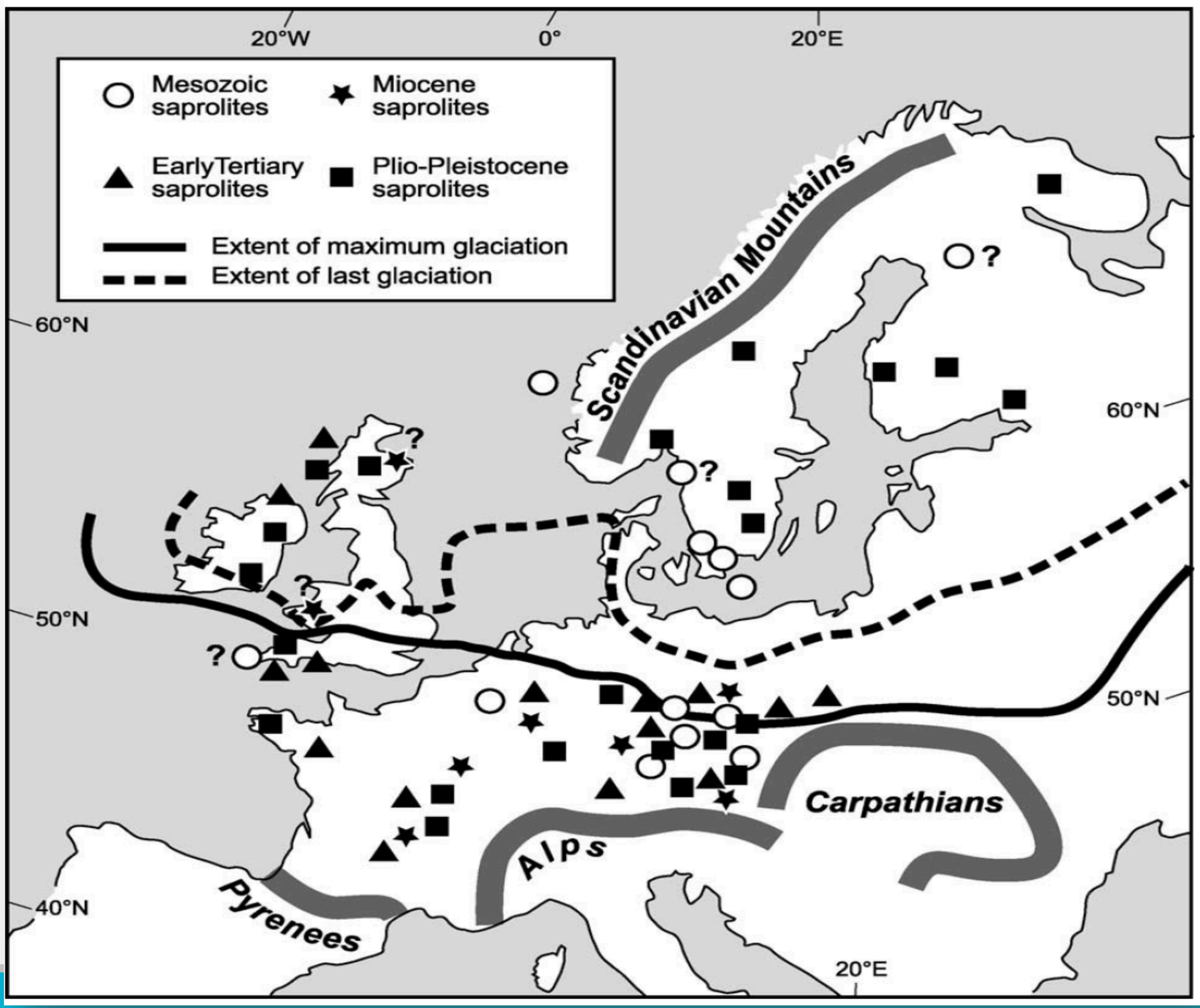
Aggressive chemical changes under weathering

Geographical distribution of intensed weathered landscapes: Palaeotropical residual regions: Distribution of climatic domains/Ni-Co lateritic and bauxite deposits

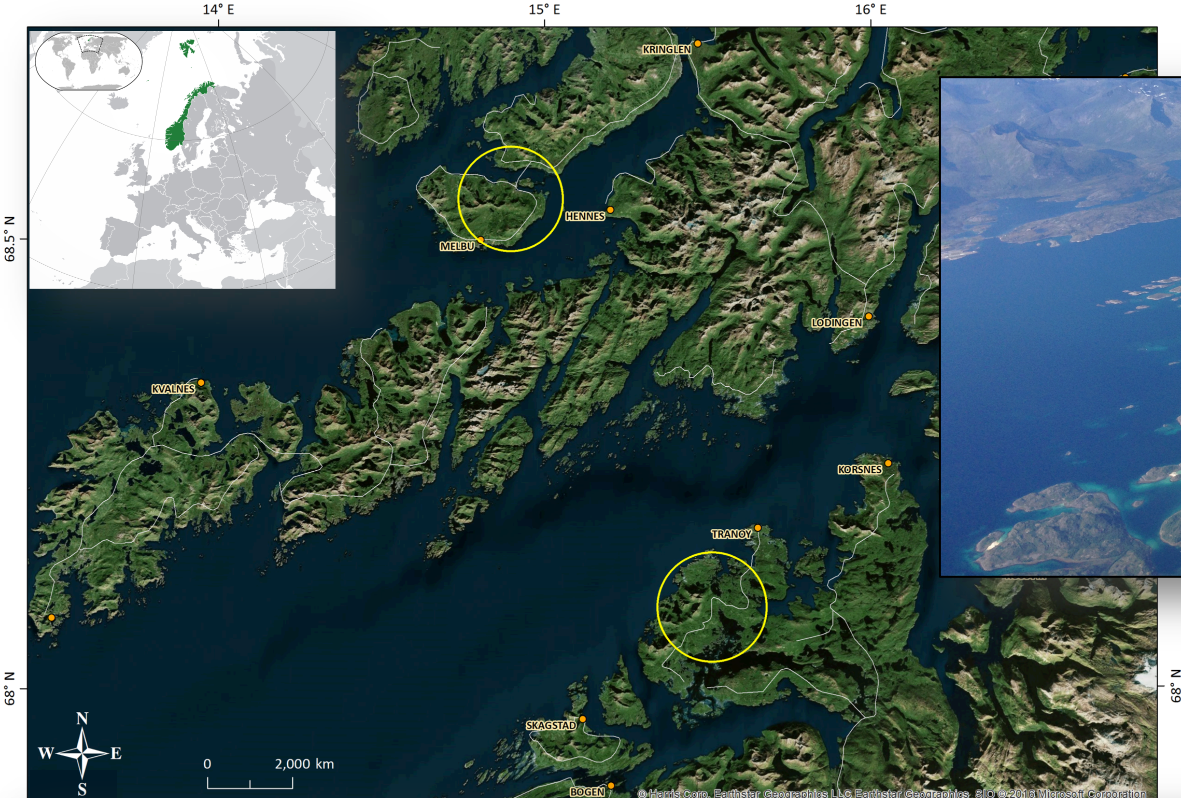


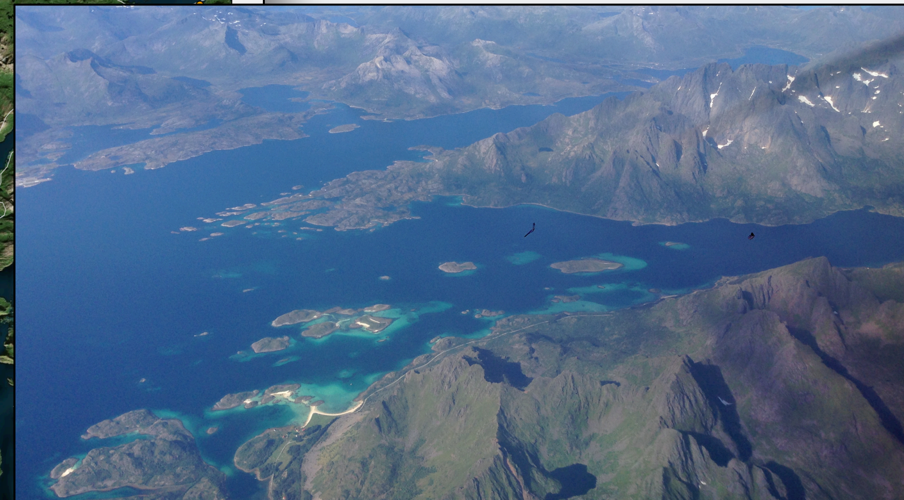
(González-Álvarez et al., 2016)

Large weathering pockets in the Artic …And all through Europe



(Migón and Lidmar-Bergström , 2002)





Hadseloy and Hamuroy islands

(González-Álvarez and Brønner, 2015)

ata and landscape understanding (e.g., stratigraphic vertical and lateral variability).

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Why CIA secular variations do not reflect in the river sedimentary budget atmospheric evolution?

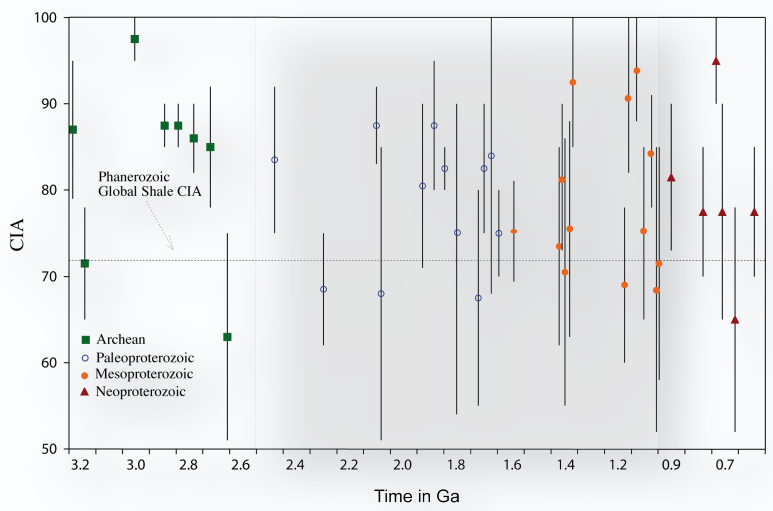
(1) The CIA index quantifies reasonably chemical weathering intensity;

(2) Rapid change in climatic conditions;

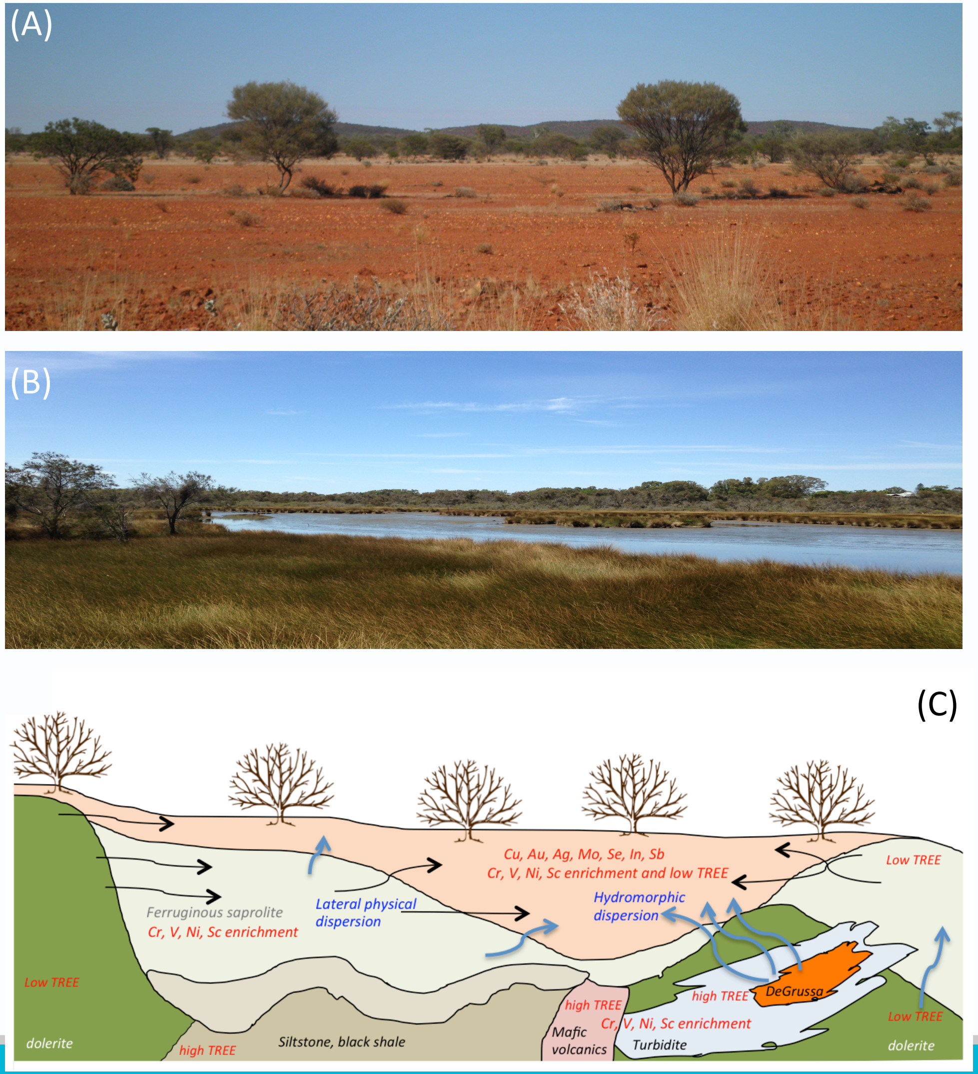
(3) Weathering alteration can happen at extremely fast rates (1000's years) and be geochemically very aggressive; and

(4) Weathering products are preserved in large pockets all over the continents even after intense glacial periods;

Weathering overprinting and mixing



Weathering overprinting and the cannibalistic landscapes in Australian



(Gonzalez-Alvarez et al., in review)

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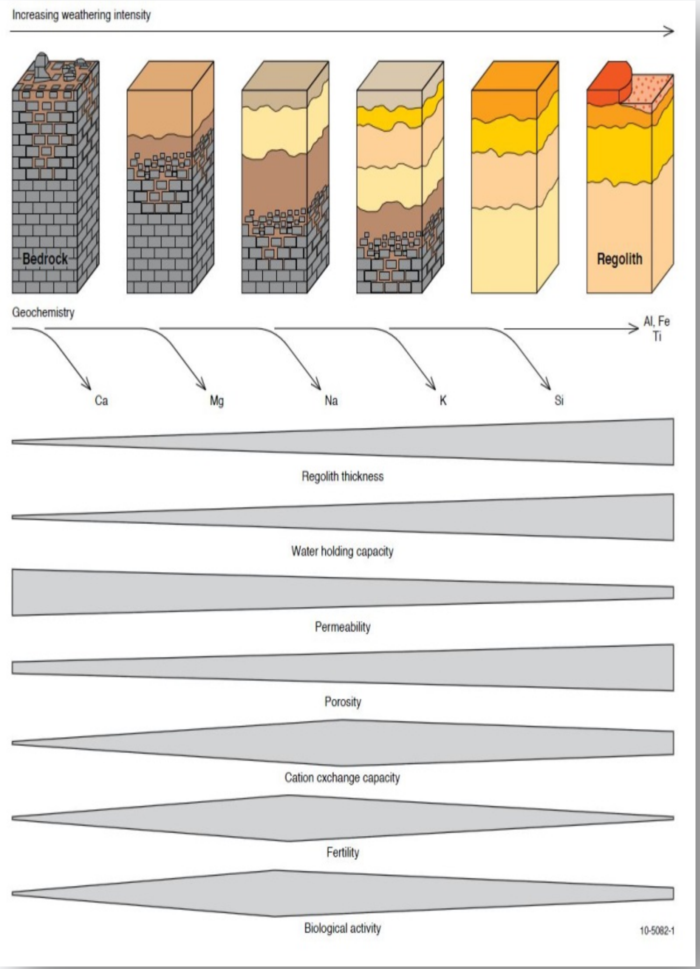
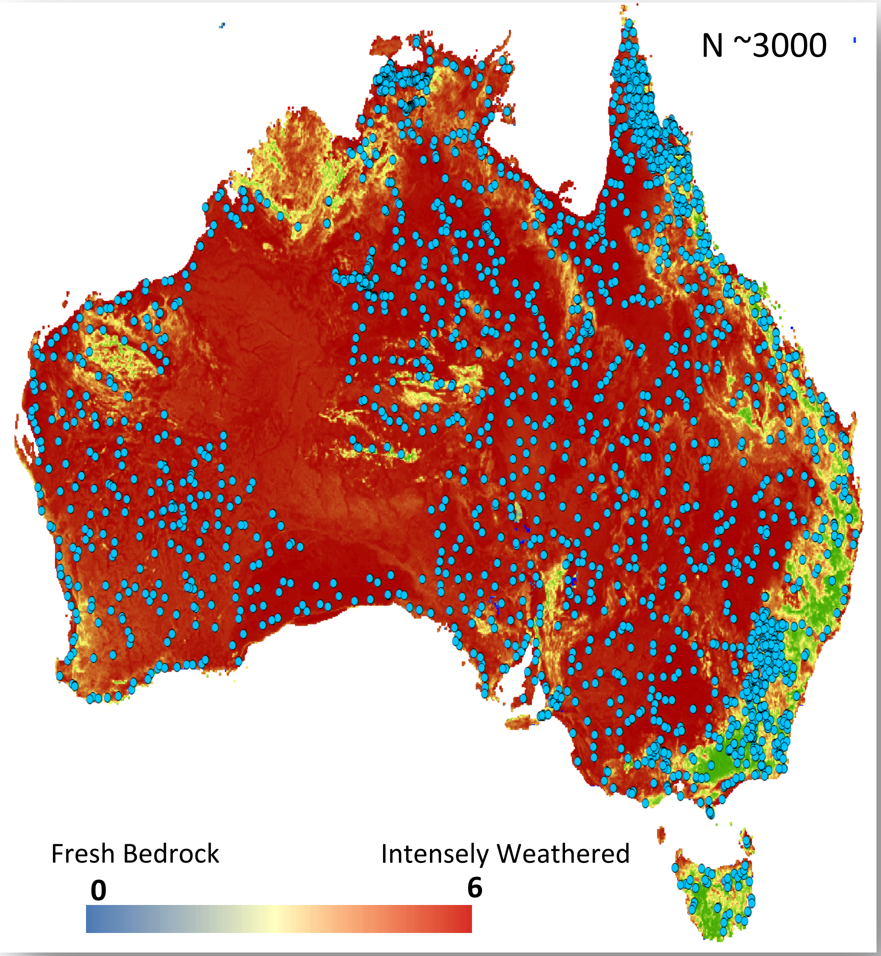
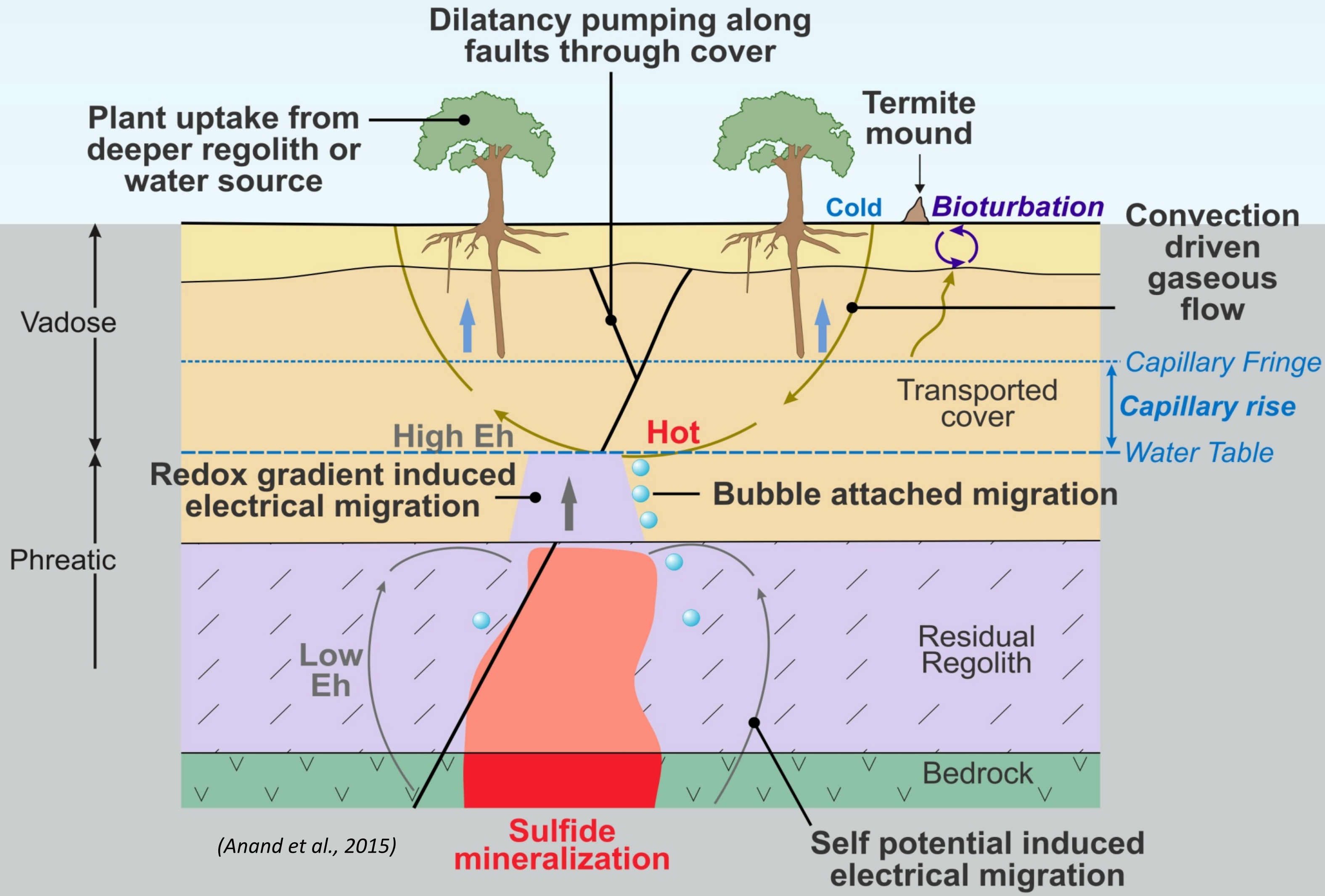
Weathering intensity distribution in Australia



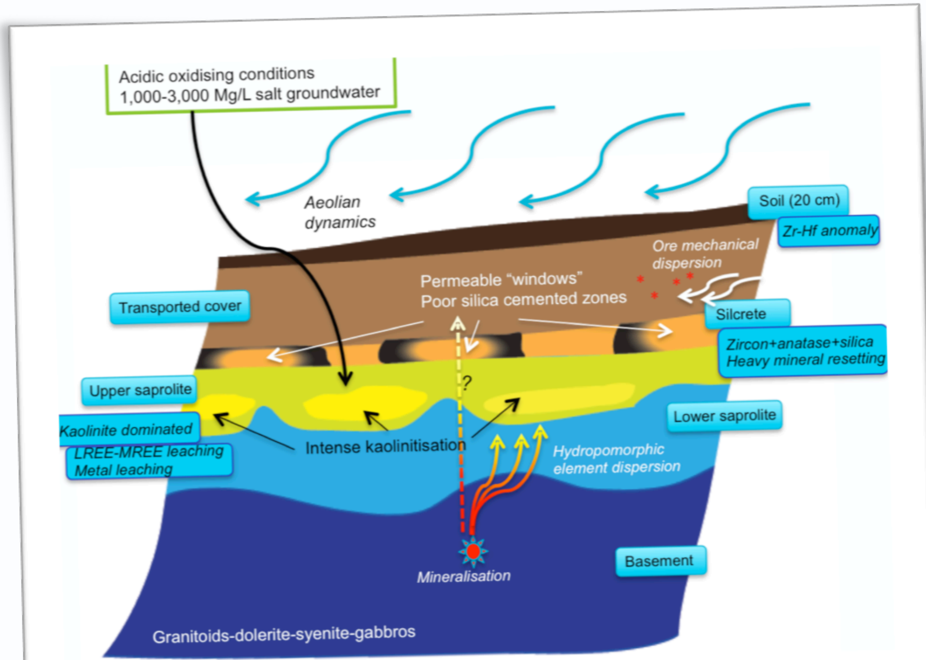


(Modified after Geoscience Australia, Minerals Forum; Perth, 12 December 2017)

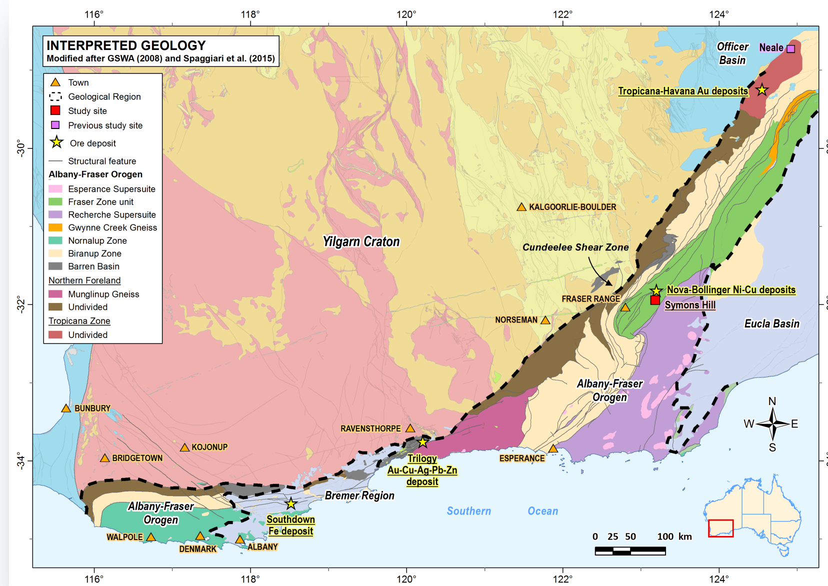
Landscape geochemistry: Trace element dispersion mechanisms in the cover

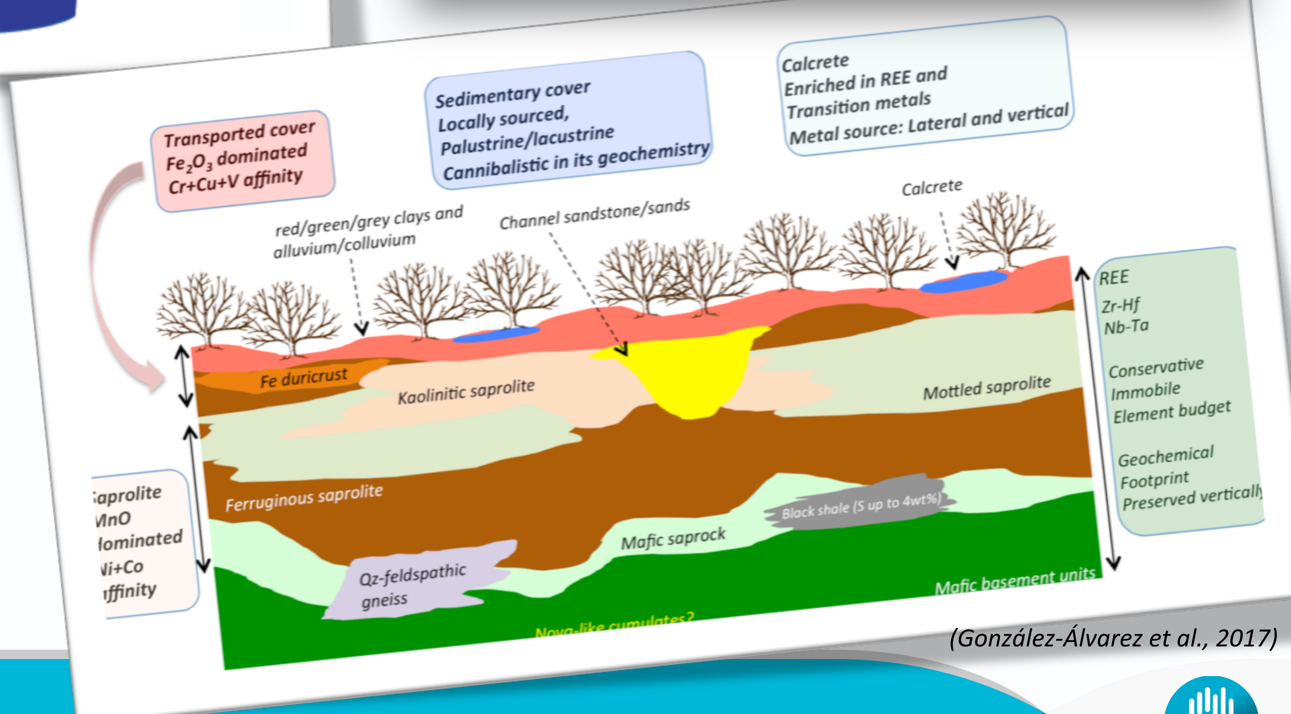


(Anand et al., 2015)



(González-Álvarez et al., 2016)

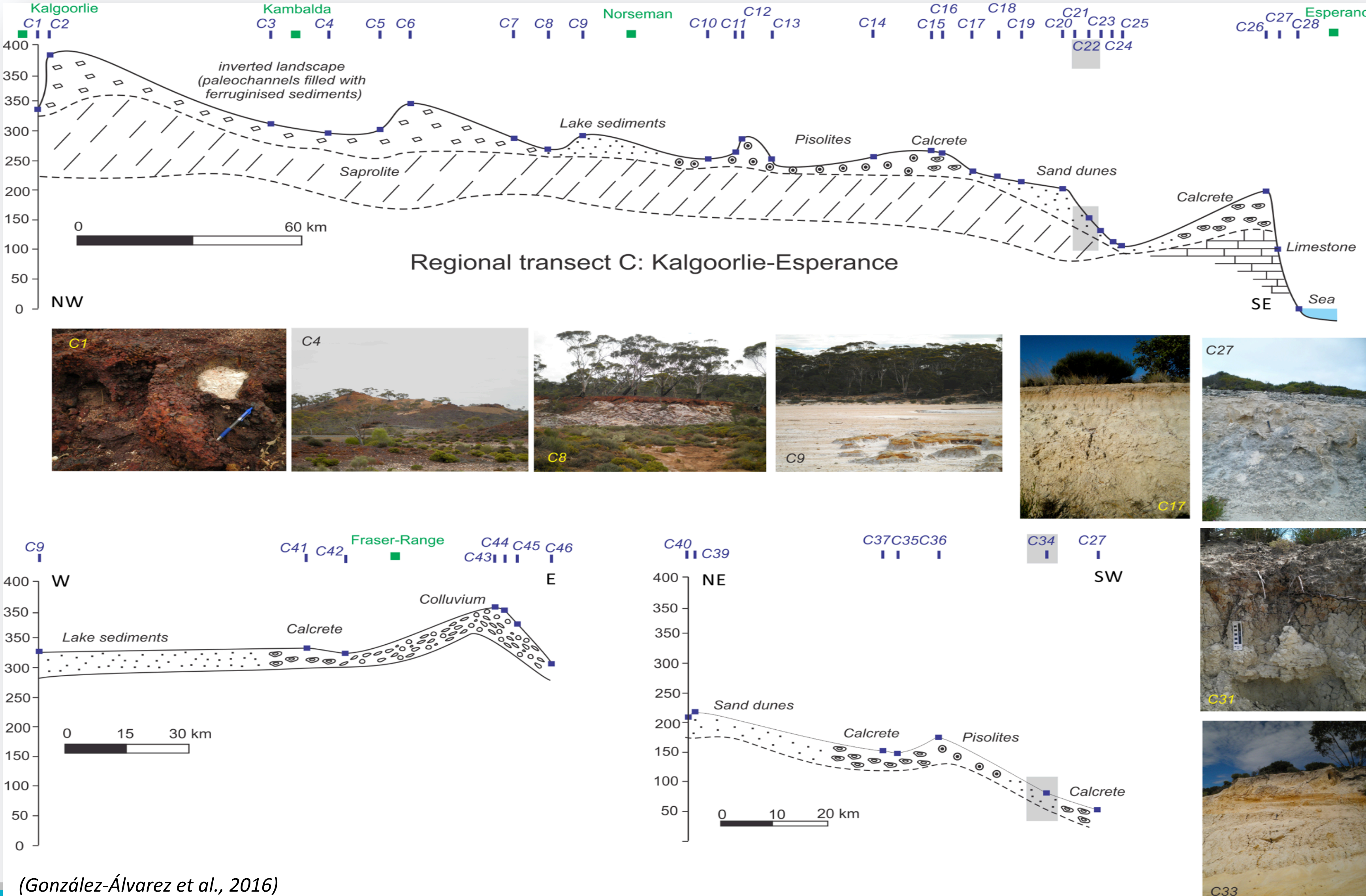




(González-Álvarez et al., 2017)

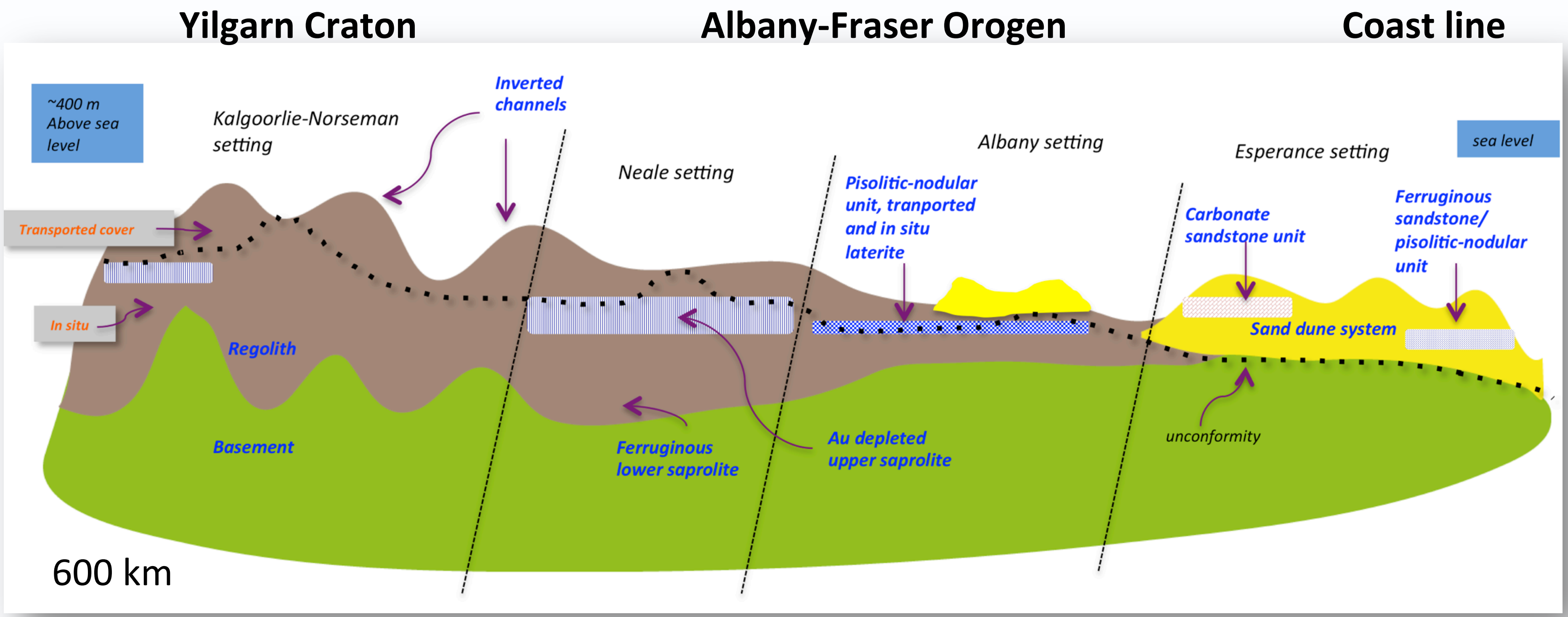
Geochemical exploration models at tenement and target scale

Landscape evolution at large-scale



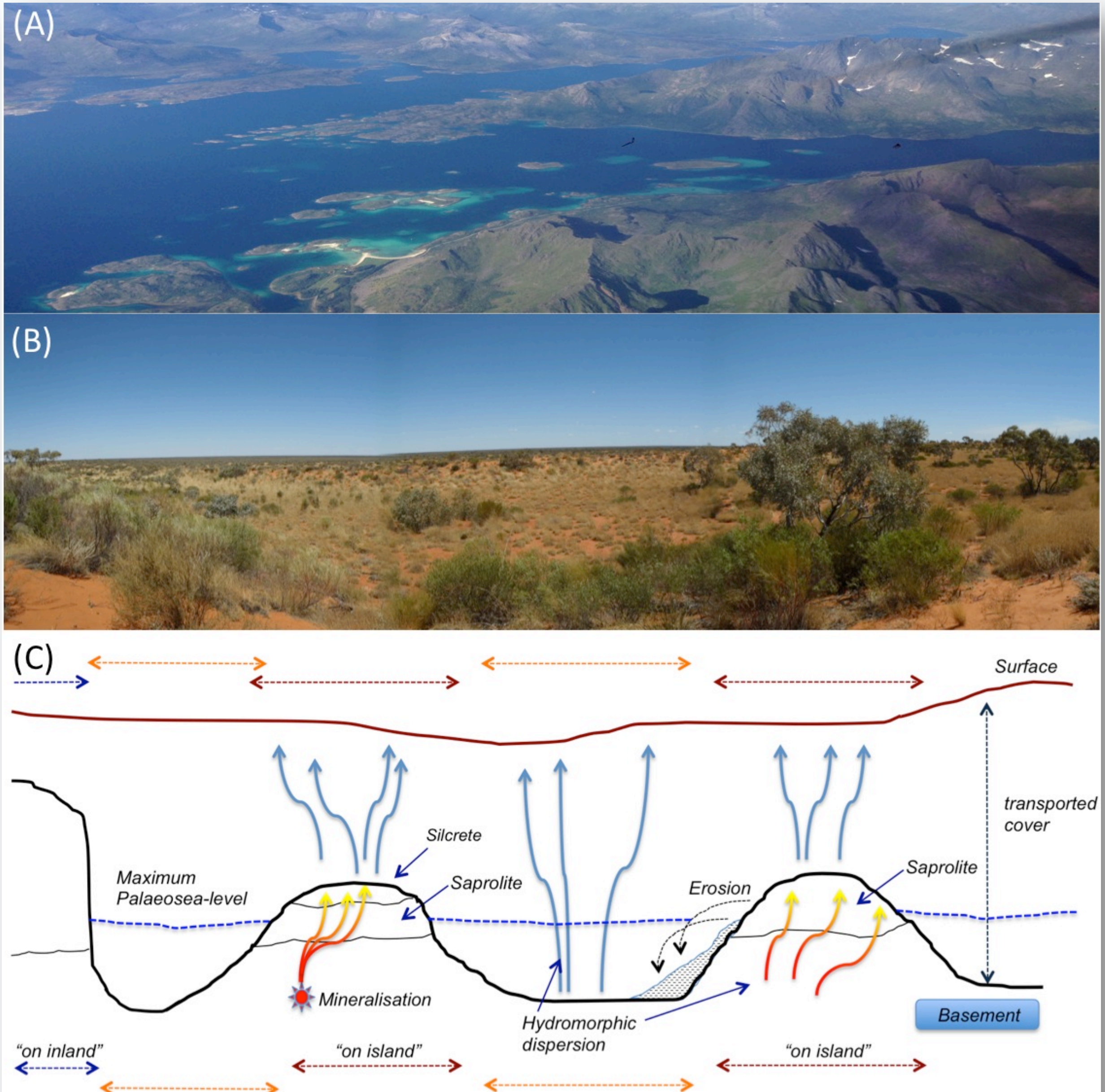
(González-Álvarez et al., 2016)

Landscape variability at large-scale



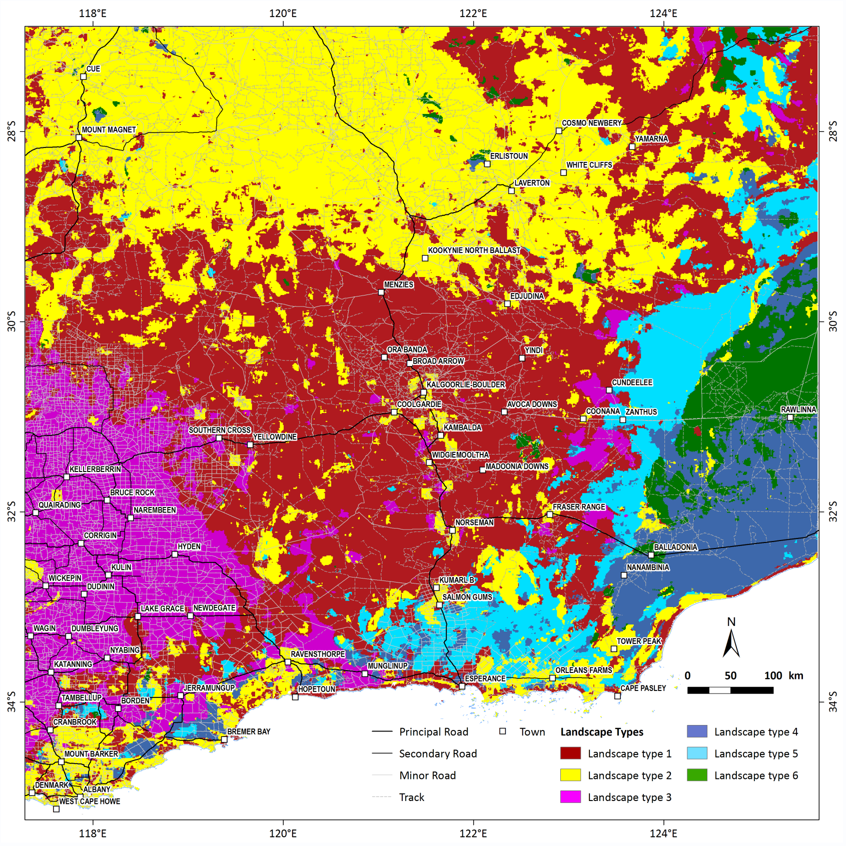
(González-Álvarez et al., 2016)

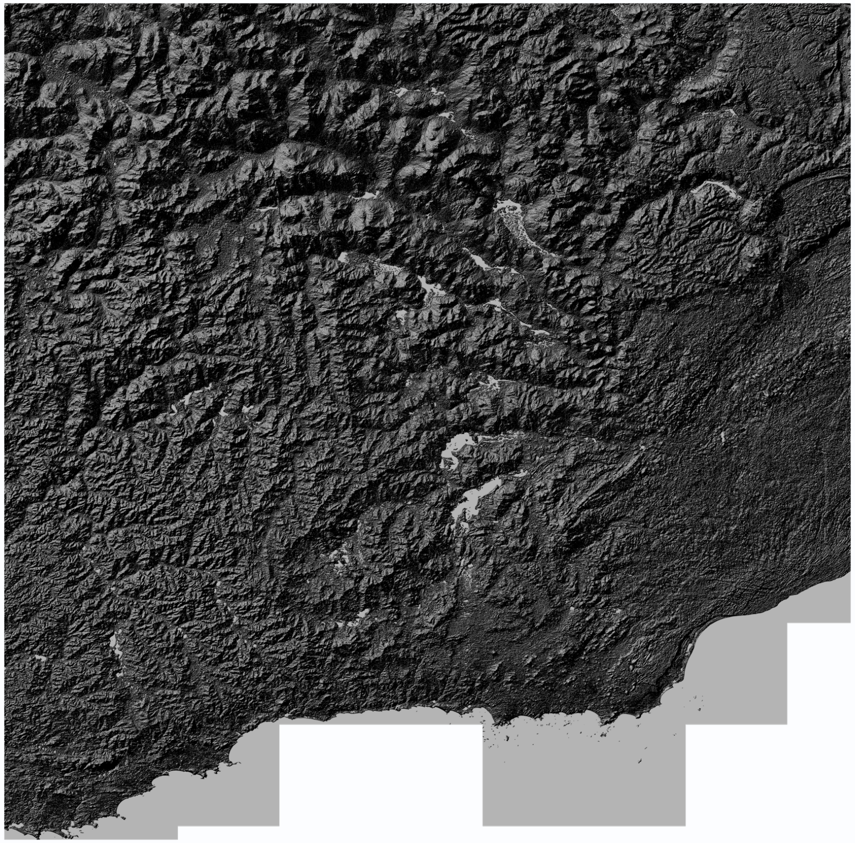
Landscape geochemistry at large-scale



(González-Álvarez et al., 2016)

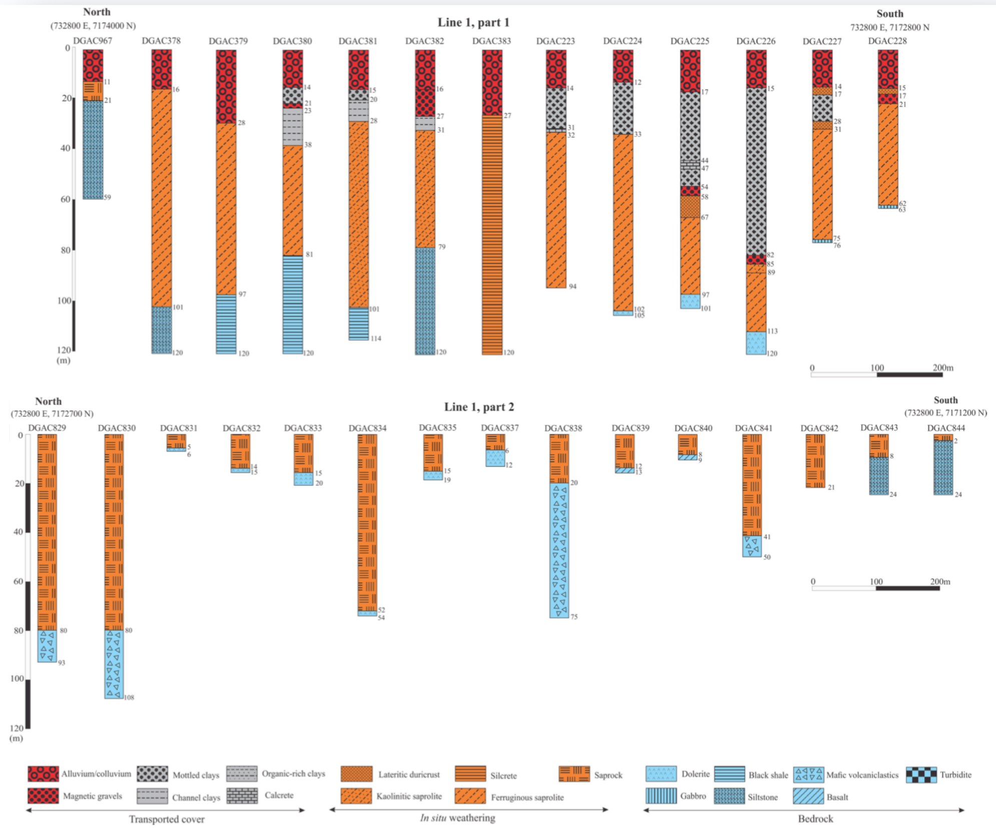
Landscape mapping based on surface geometric features: linking landscape types to stratigraphy and geochemistry at cratonic scale

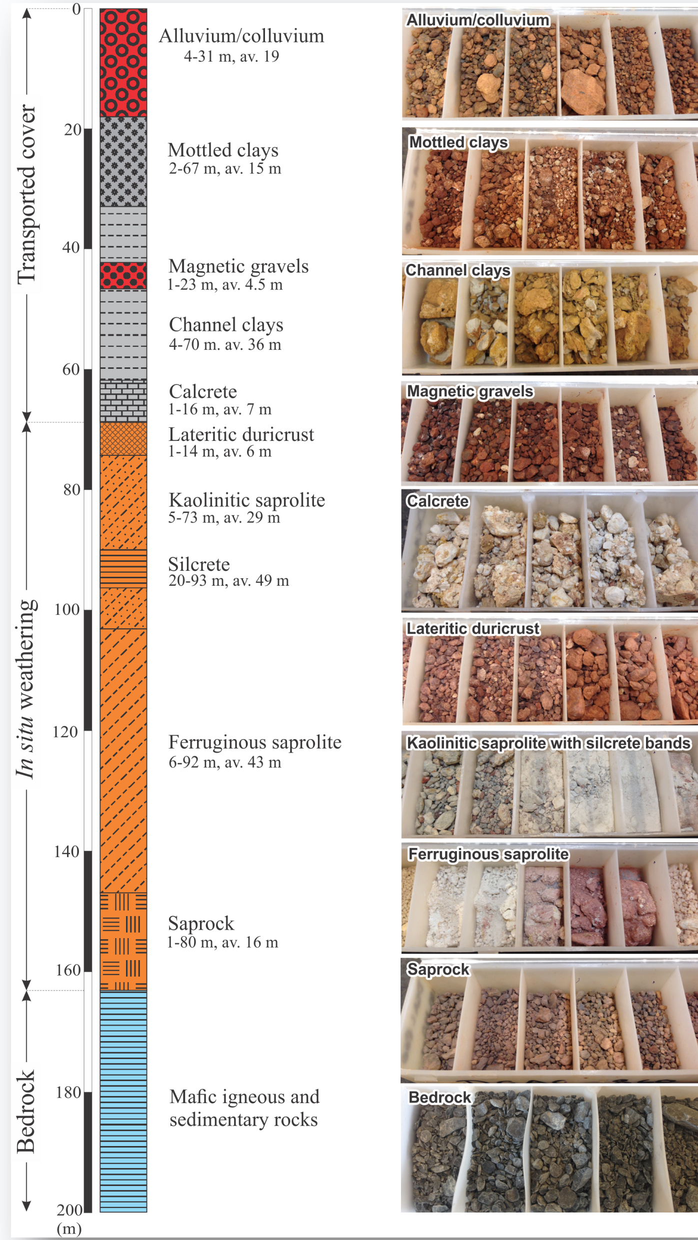




(Smith 2017 personal communication; González-Álvarez et al 2017; Pernreiter et al., 2018)

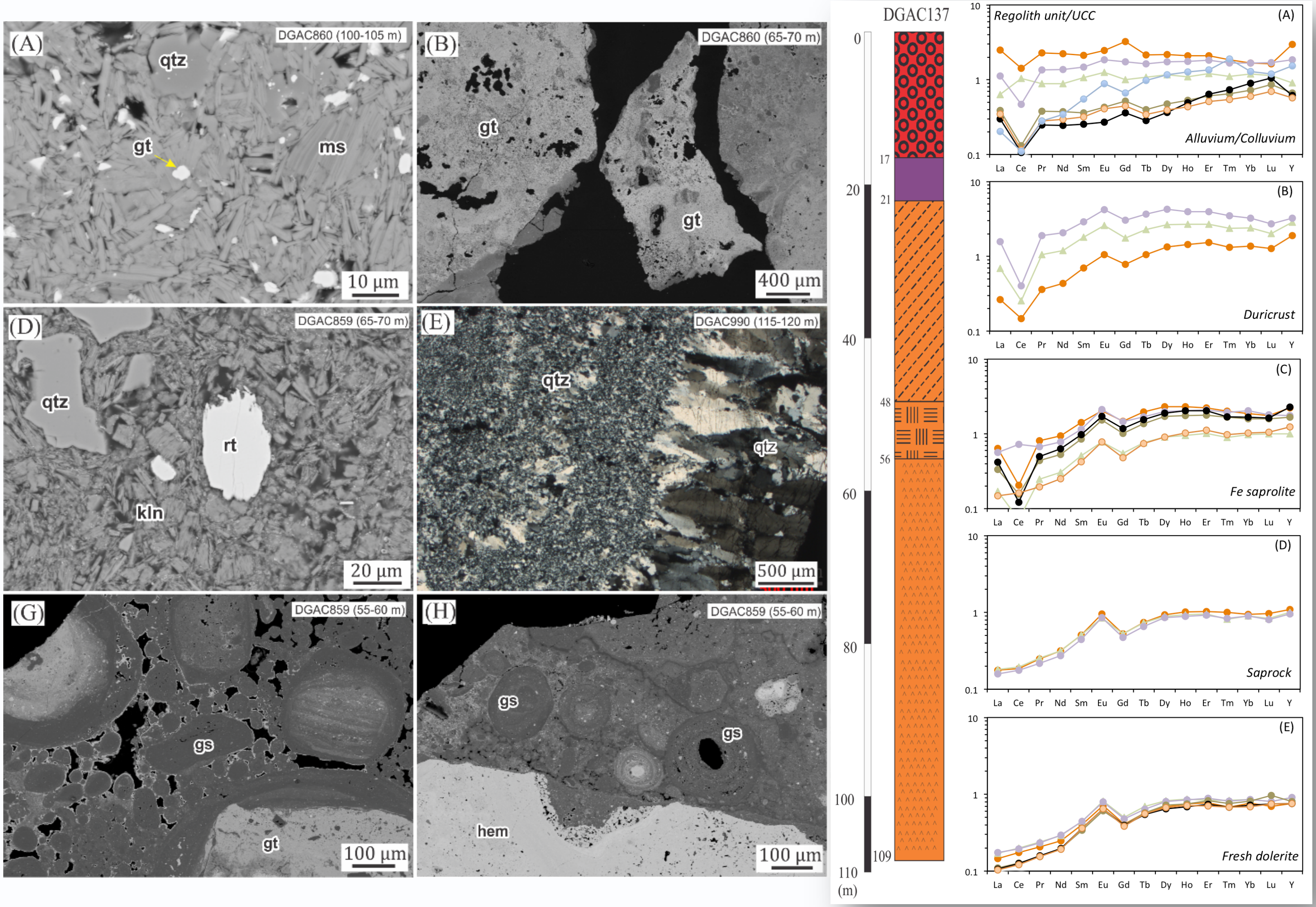
Linking landscape type with stratigraphy





(González-Álvarez and Salama et al., 2016)

Linking stratigraphy with mineralogy and geochemistry



(González-Álvarez and Salama et al., 2016)

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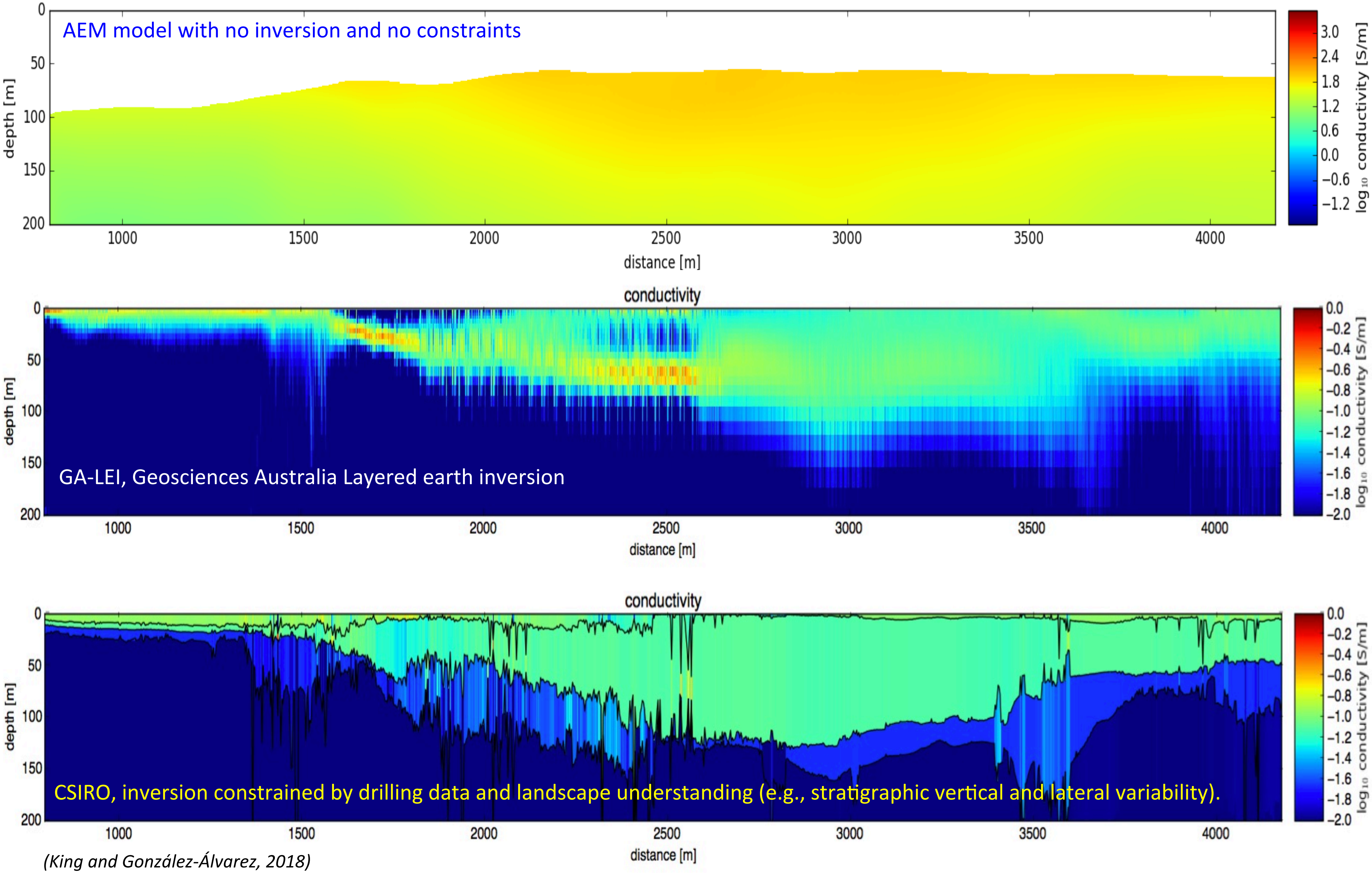
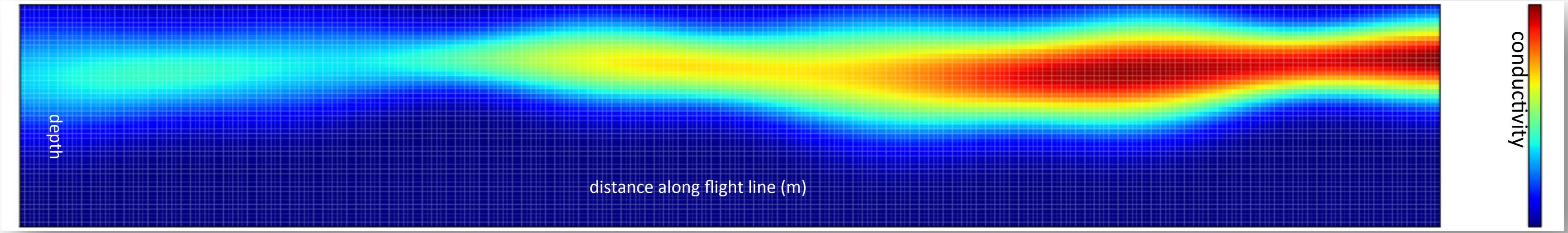
Inverting and constraining electromagnetic models



(King and González-Álvarez, 2018)

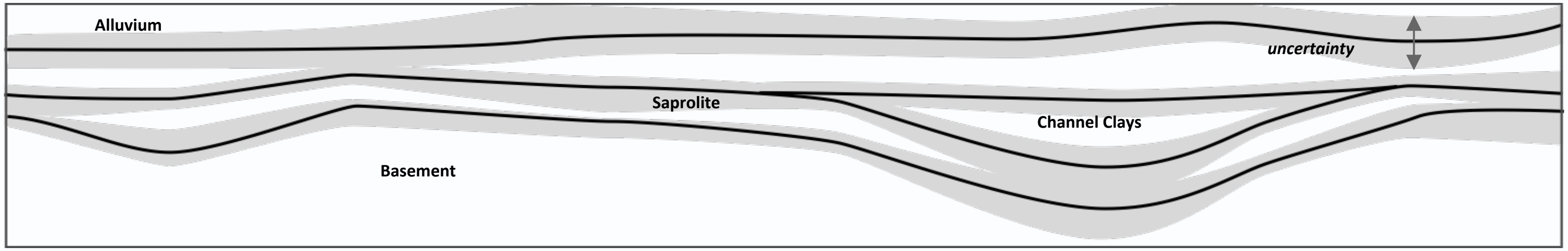
Geolophysicall-meaningful inversions

Replace this (conductivity section):



with this (geology):

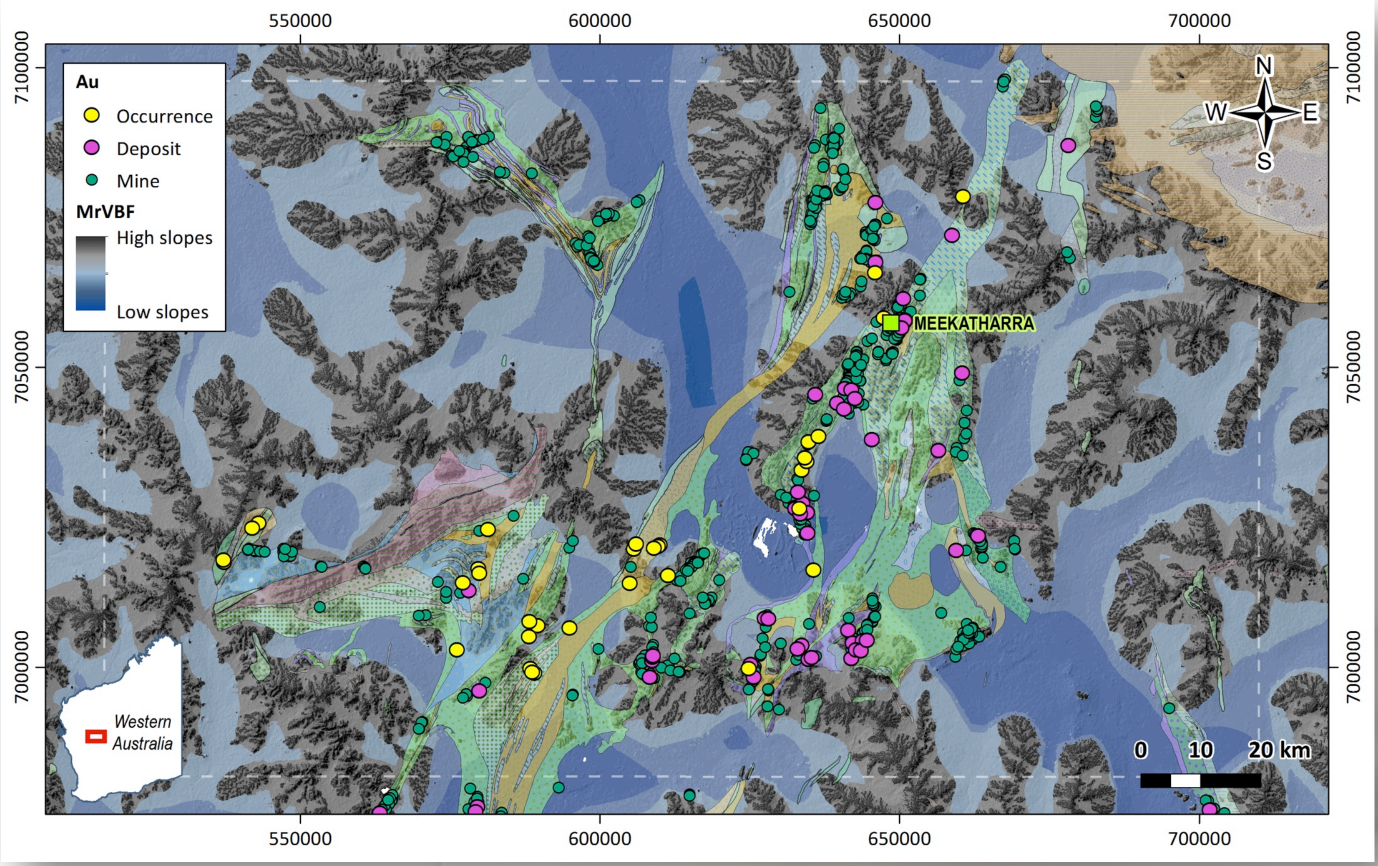
how to use drilling, landscape and geochemical understanding to develop a good prior probability for the cover.



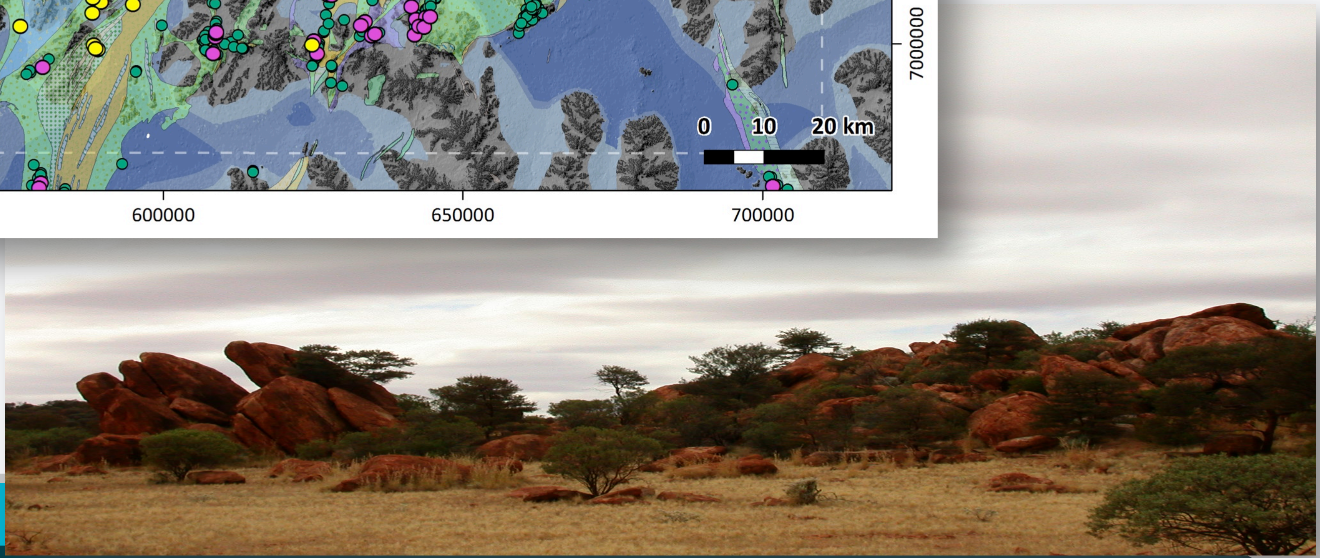
Innovation: ***To assess what geological information is important for the model and how to incorporate into the inversion to produce the best geological model of the area.***

(King and González-Álvarez, 2018)

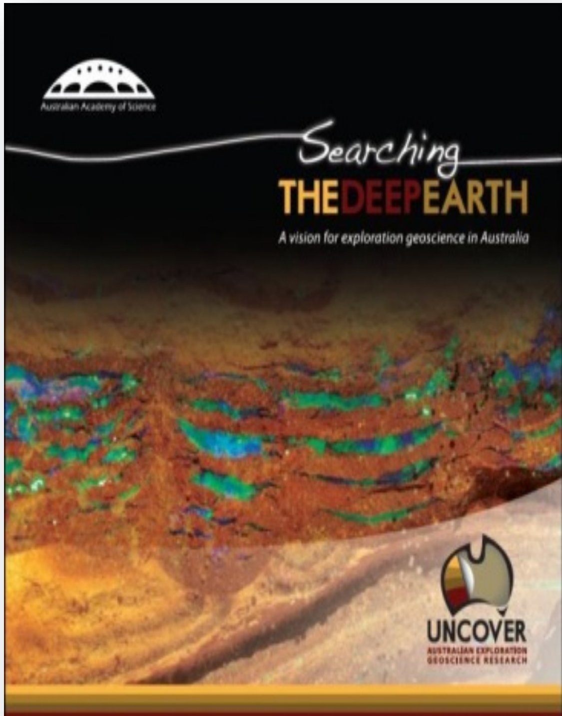
Asymmetric distribution of mineral discoveries



Murchison Province, Meekatharra goldfields

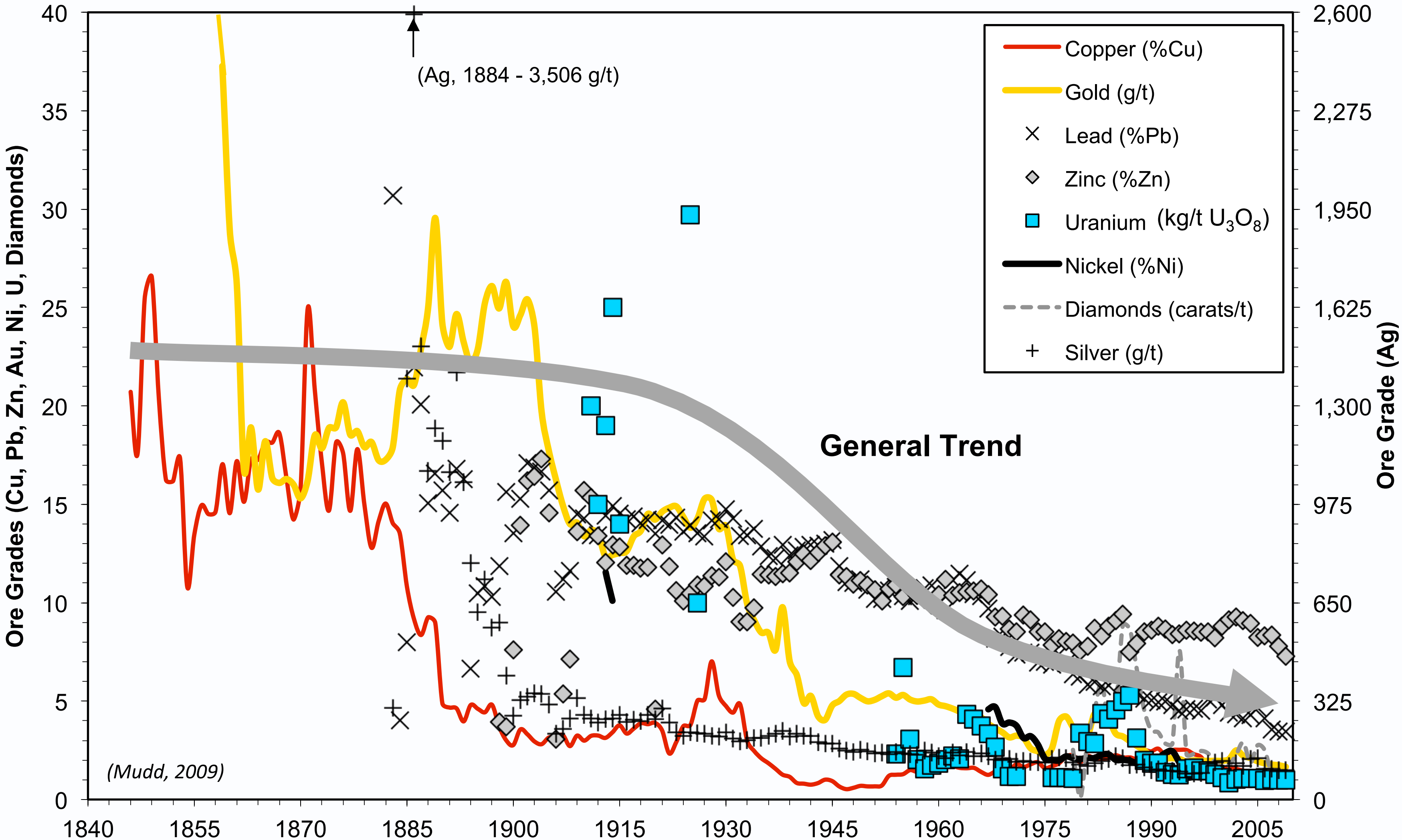


Looking into the future: The Uncover initiative

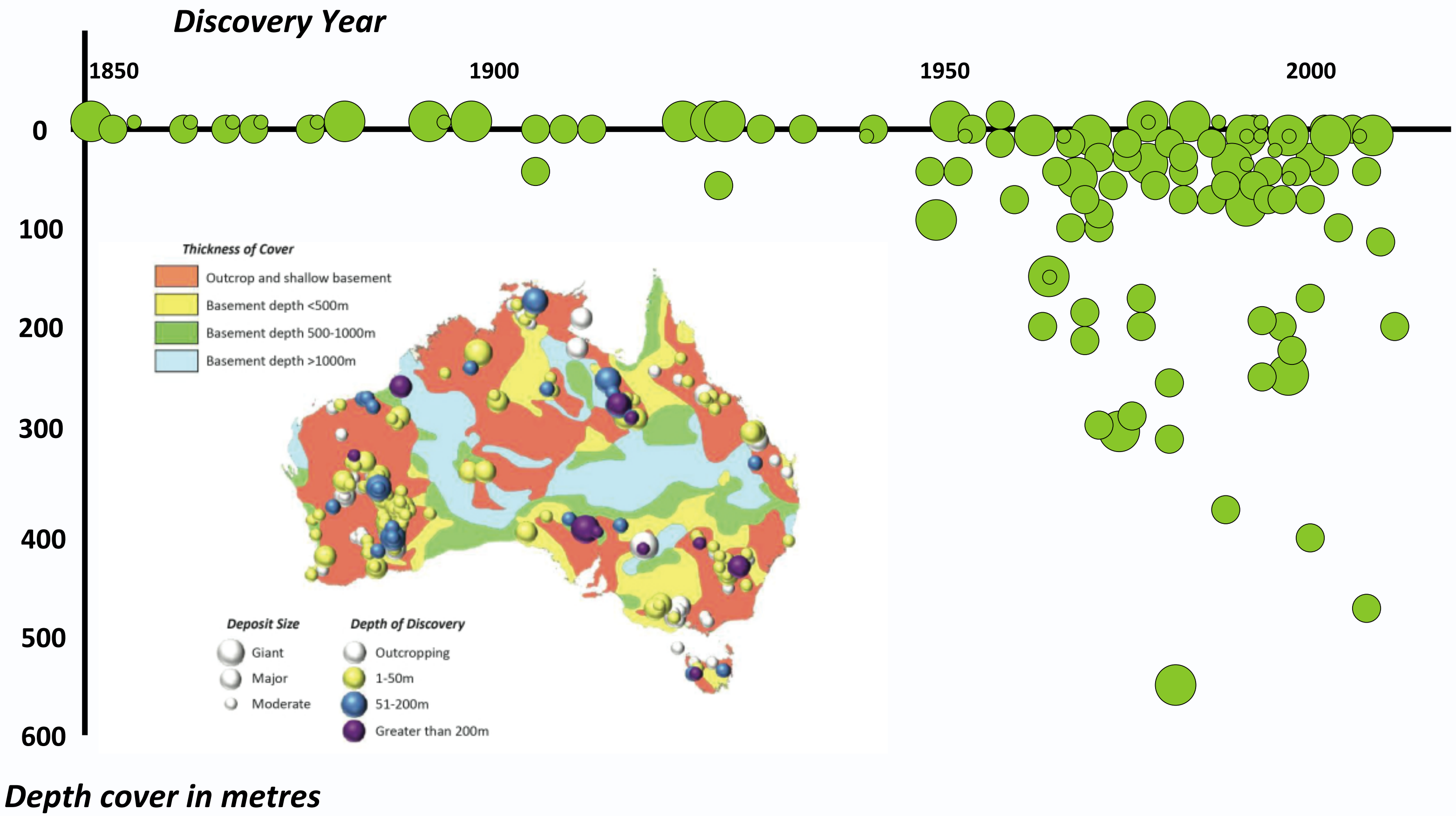


Focus Area	Priority	Data compilation	Data acquisition	Research	Technology development
Understand type, age, depth of cover. Compile and produce 3D Geological and Paleosurface maps and layers	Highest Priority	■	■		
Depth-to-basement and cover-characteristics, imaging from new targeted airborne National (20km) EM surveys	Highest Priority	■	■	■	■
Compile and integrate models and data to build 3D architecture and composition of Australian whole lithosphere	Highest Priority	■			
Acceleration and completion of national AusLamp long period MT (55km spacing) program	Highest Priority		■		
Improve understanding and develop definitions of mineral systems across scales for different model/deposit types and commodities	Highest Priority			■	
Characterise and mapping whole mineral system footprint signatures (proximal to distal)	Highest Priority	■	■	■	
Targeted and prioritised cover/paleosurface horizons and basement re-sampling and new sampling via Onshore Stratigraphic drilling initiative	High priority		■		
Improve and refine understanding of geochemical dispersion in post mineralisation cover sequences	High priority	■		■	■
Map metal fertility of lithosphere (current state) structures, domains and basins	High Priority	■		■	
Data acquisition - Australian Seismic Array ASA	High Priority		■		
Acquire ~4km grid of gravity over continent	High Priority		■		
Create and update a fully 3D current architectural interpretation of Australian lithosphere	High Priority	■		■	
Targeted geochron data acquisition of mineral occurrences and priority basins and concealed basment via Strat drill program	High Priority		■		
Increased understanding of genesis and development of major trans-lithospheric geodynamic faults/lineaments through time	High Priority			■	
Create new fertility tools to understand and map metal fertilities for specific geological, tectonic and metallogenic events over time	High Priority			■	
Maximise size of detectable signature and understand detection levels and capabilities	High Priority			■	

Australian/World Mineral Resource Demand



Australian ore deposit historical view



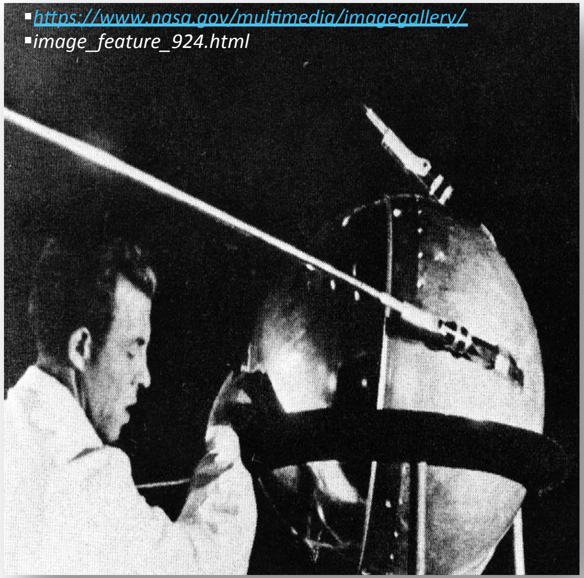
(Richard Schodde, MinEx Consulting, 2013)

(Modified from Think Tank 2010, Australia, Canberra)

Can we unlock the $1Trillion resources under cover at more than >500 m or 1000 m depth?

Of course we can!

October 4, 1957, the Soviet Union launched the Sputnik



July 21, 1969, First human to step on the Moon

Only 12 Years!
….And $100B