Nickel laterite deposits of the northern part of the Great Dyke

Geomorphology, regolith stratigraphy, geochemistry, mineralogy, distribution and genesis

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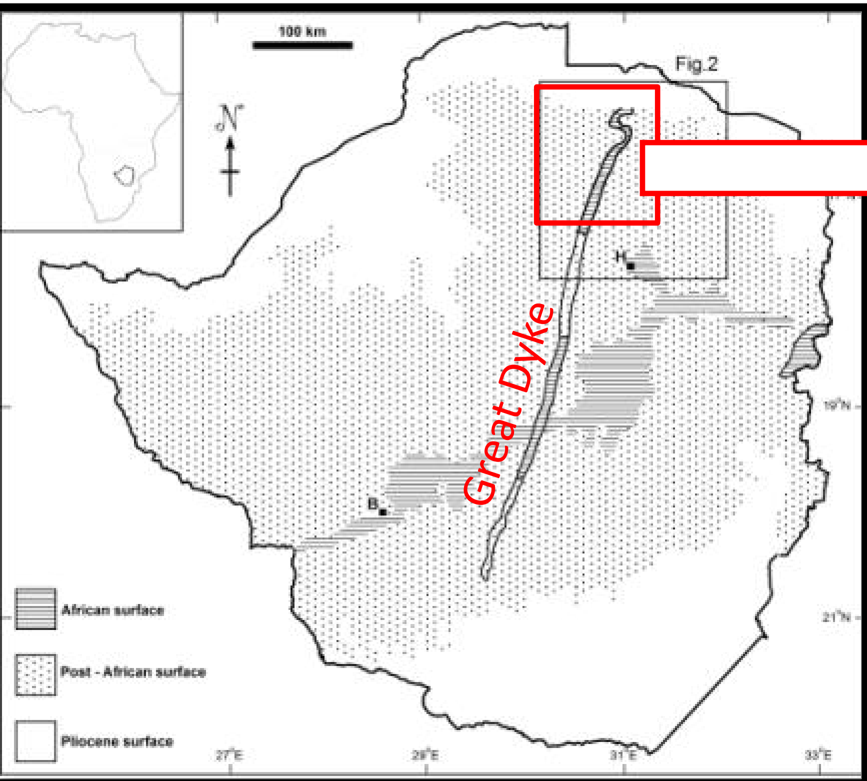
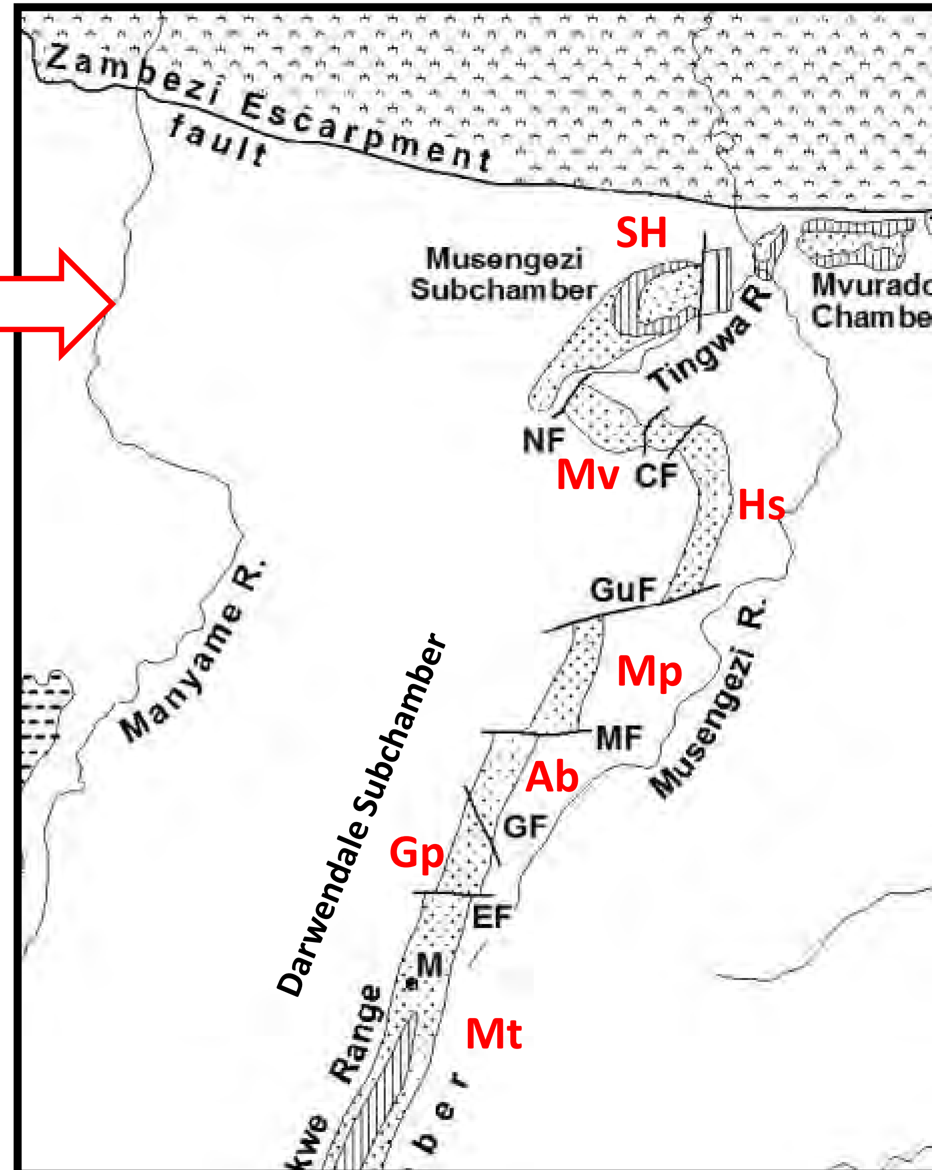
Independent geological consultant

Acknowledgements: African Consolidated Resources Limited



Location of the Great Dyke



The northern part of the Great Dyke (or the 'North Dyke')

Observations

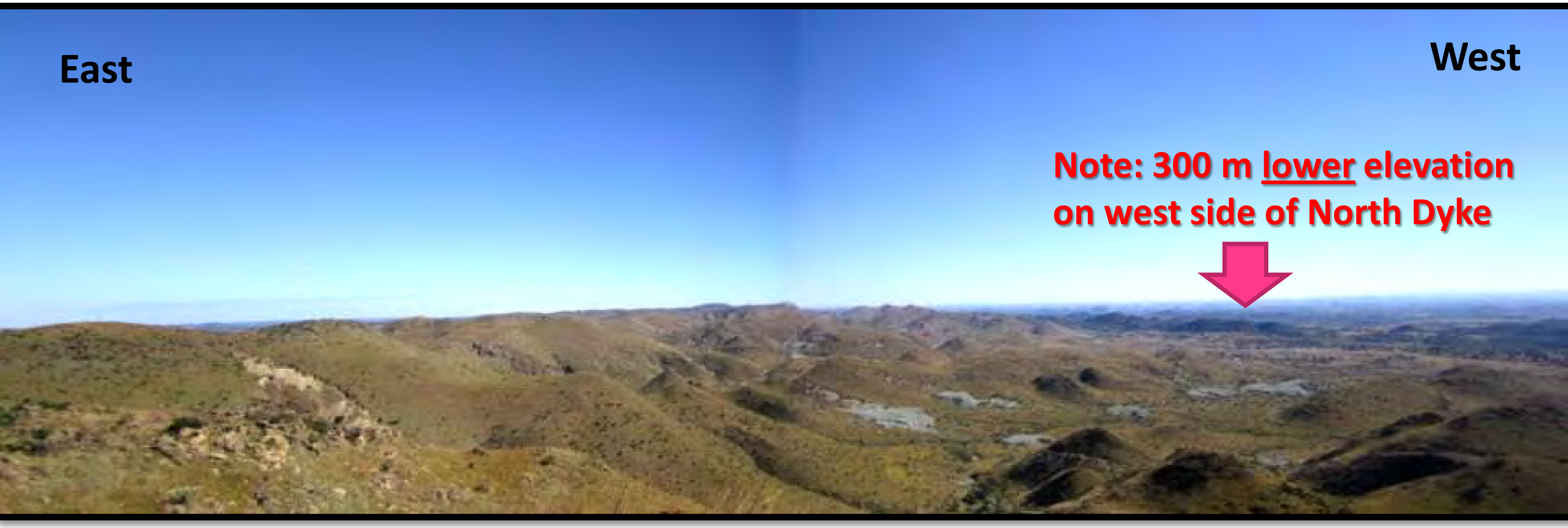
- Geomorphology of Mvukwe Range
- Nature of erosion surfaces
- Distribution of erosion surfaces
- Regolith mineralogy and textures
- Regolith geochemistry
  Nickel enrichments in surface/near surface samples
  Vertical variations in Ni, Co and major/minor oxides in drill-samples
- Probable mineralogy of nickel enrichments

Interpretation

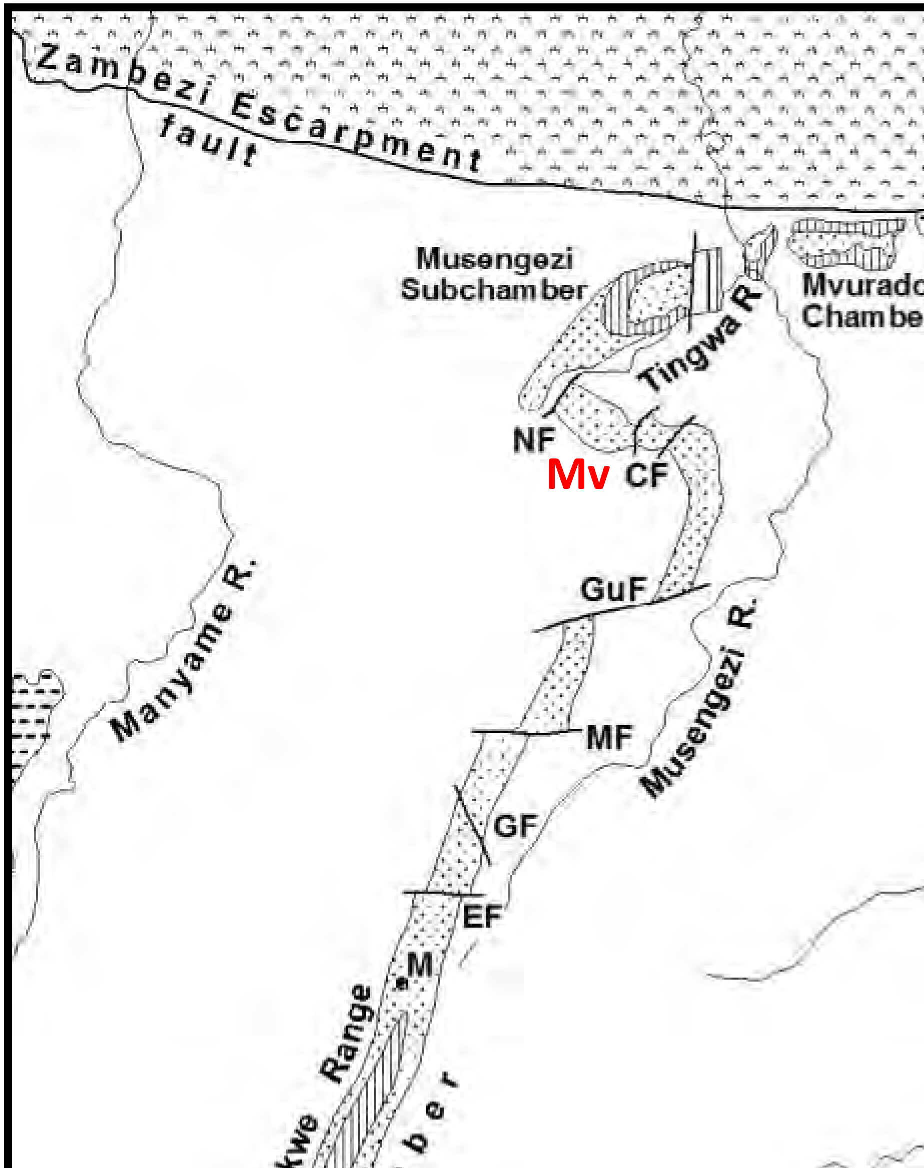
- Landscape evolution in northern Zimbabwe
- The African Surface on the North Dyke
- Uplift and rejuvenation in northern Zimbabwe
- Nickel laterite deposits on the Great Dyke

1. Geomorphology of the Mvukwe Range

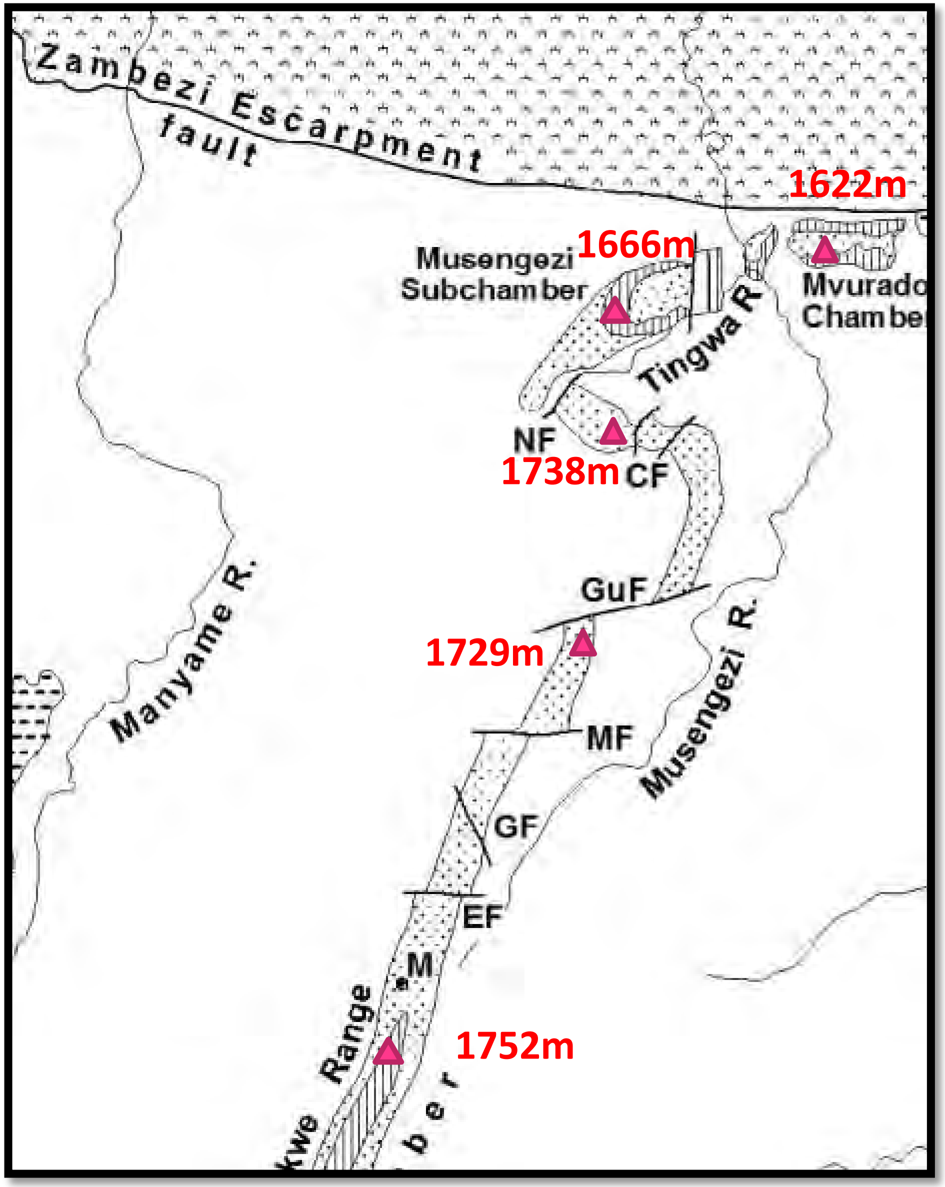
The Mvukwe Range, Aberdeen section: view east



Mutorashanga: view south

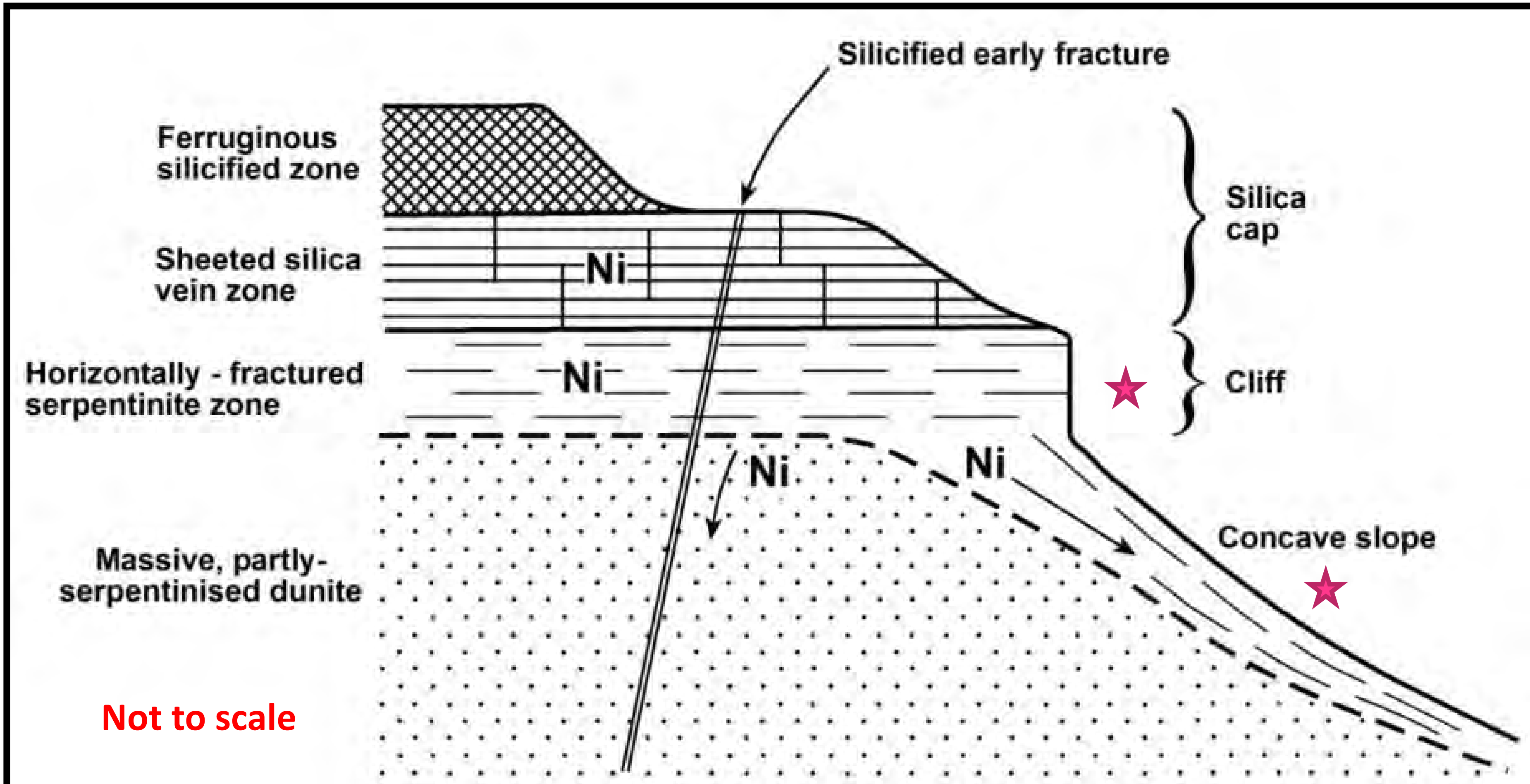


The northern part of the Great Dyke



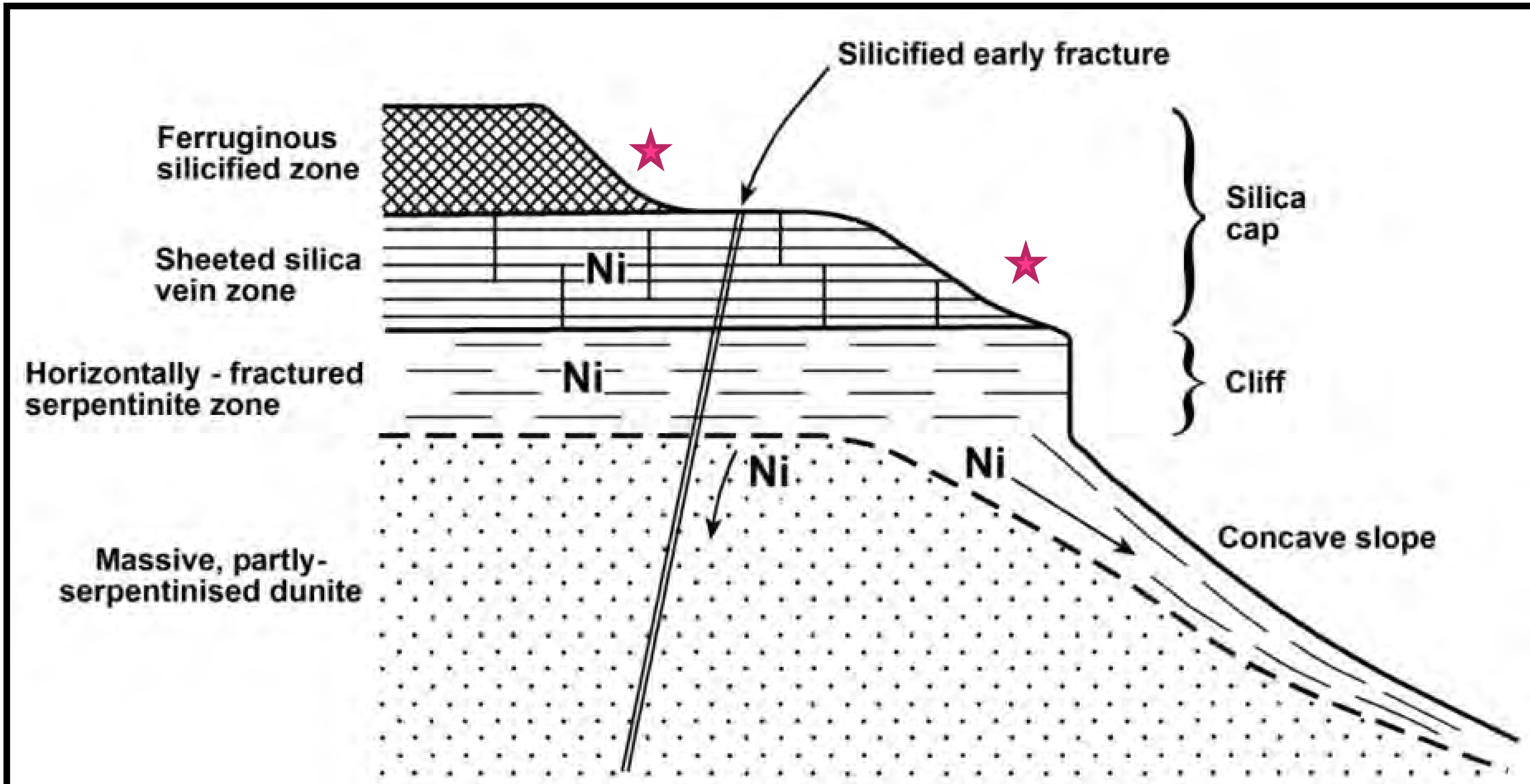
The northern part of the Great Dyke

2. Nature of Erosion Surfaces

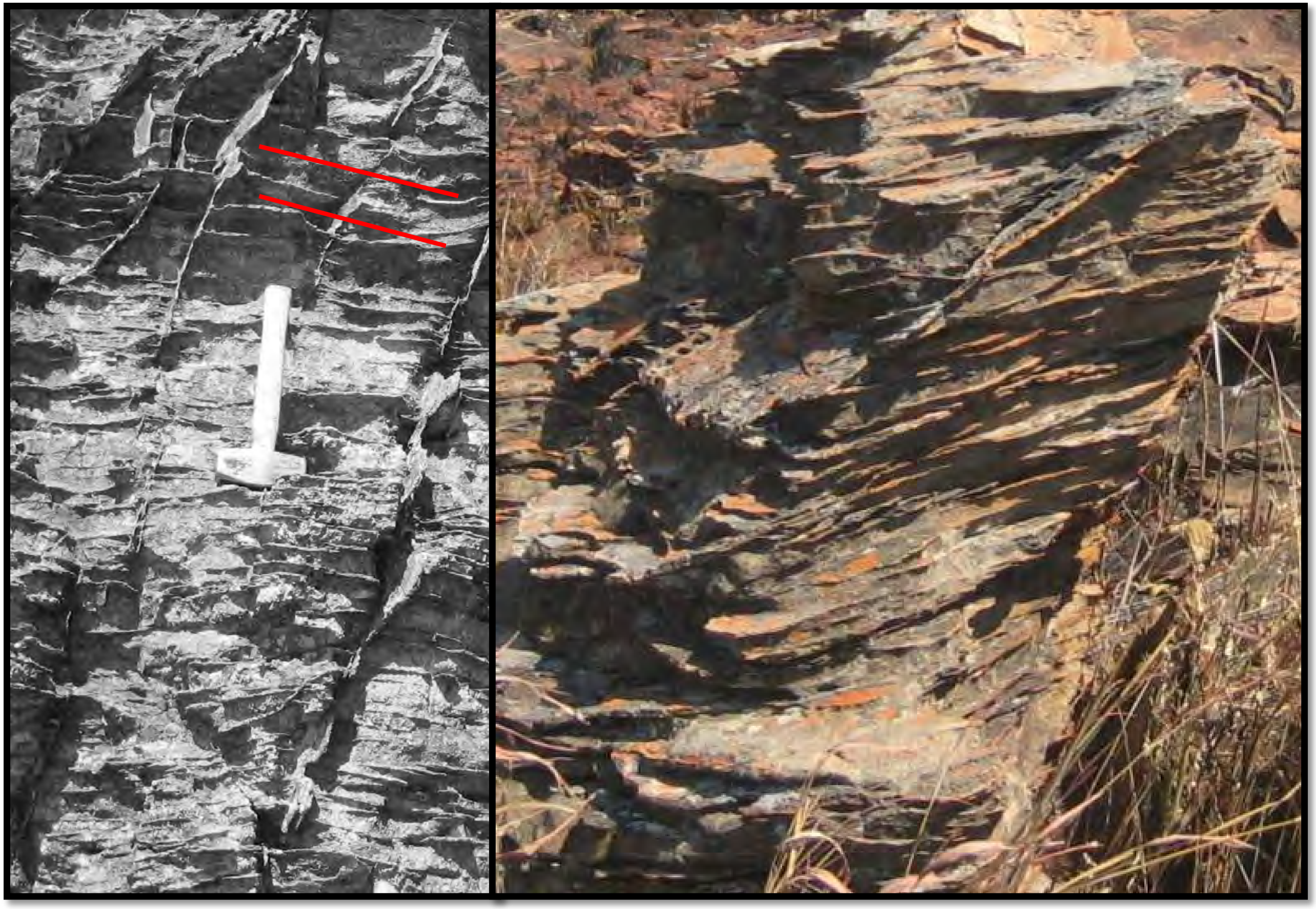


Regolith stratigraphy

Cliff-forming, horizontally fractured serpentinite



Regolith stratigraphy



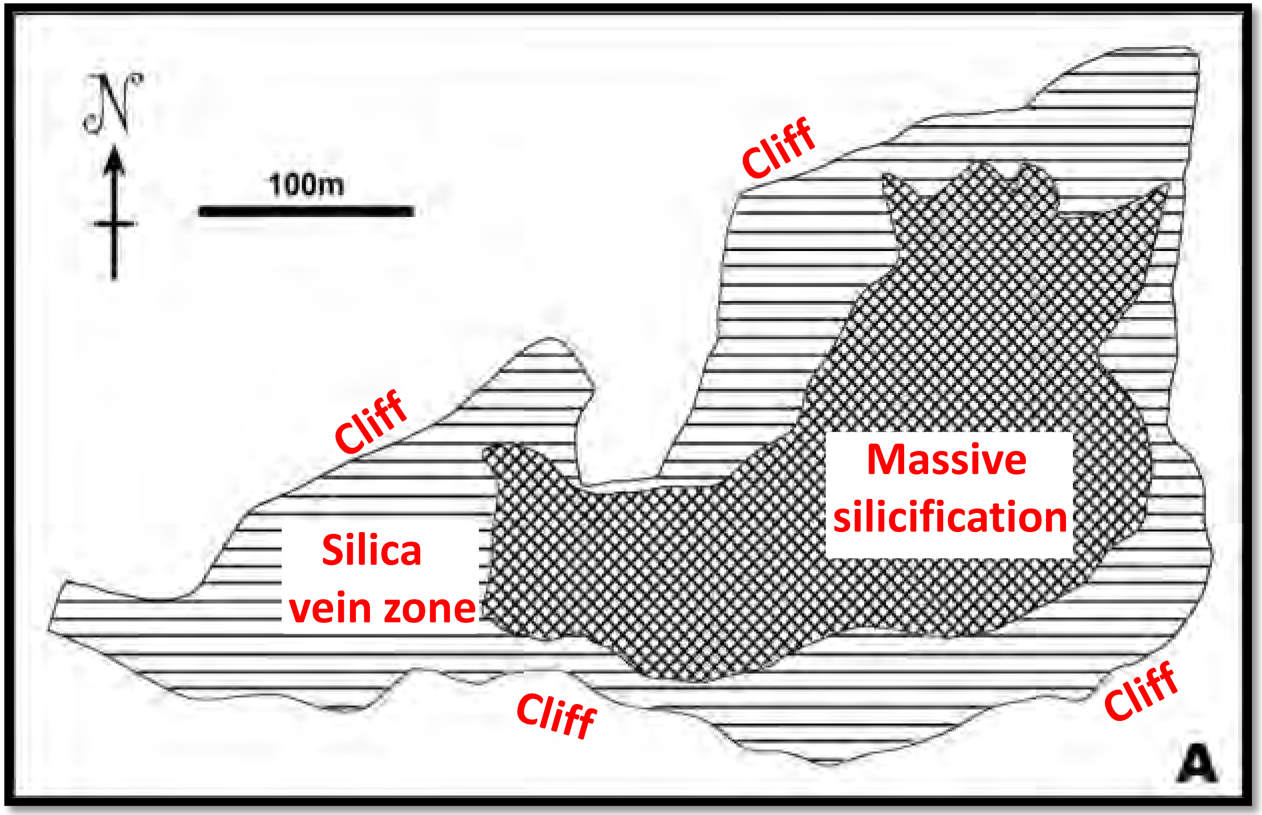
Silica cap 1: Sheeted silica vein zone

Crude siliceous stockwork

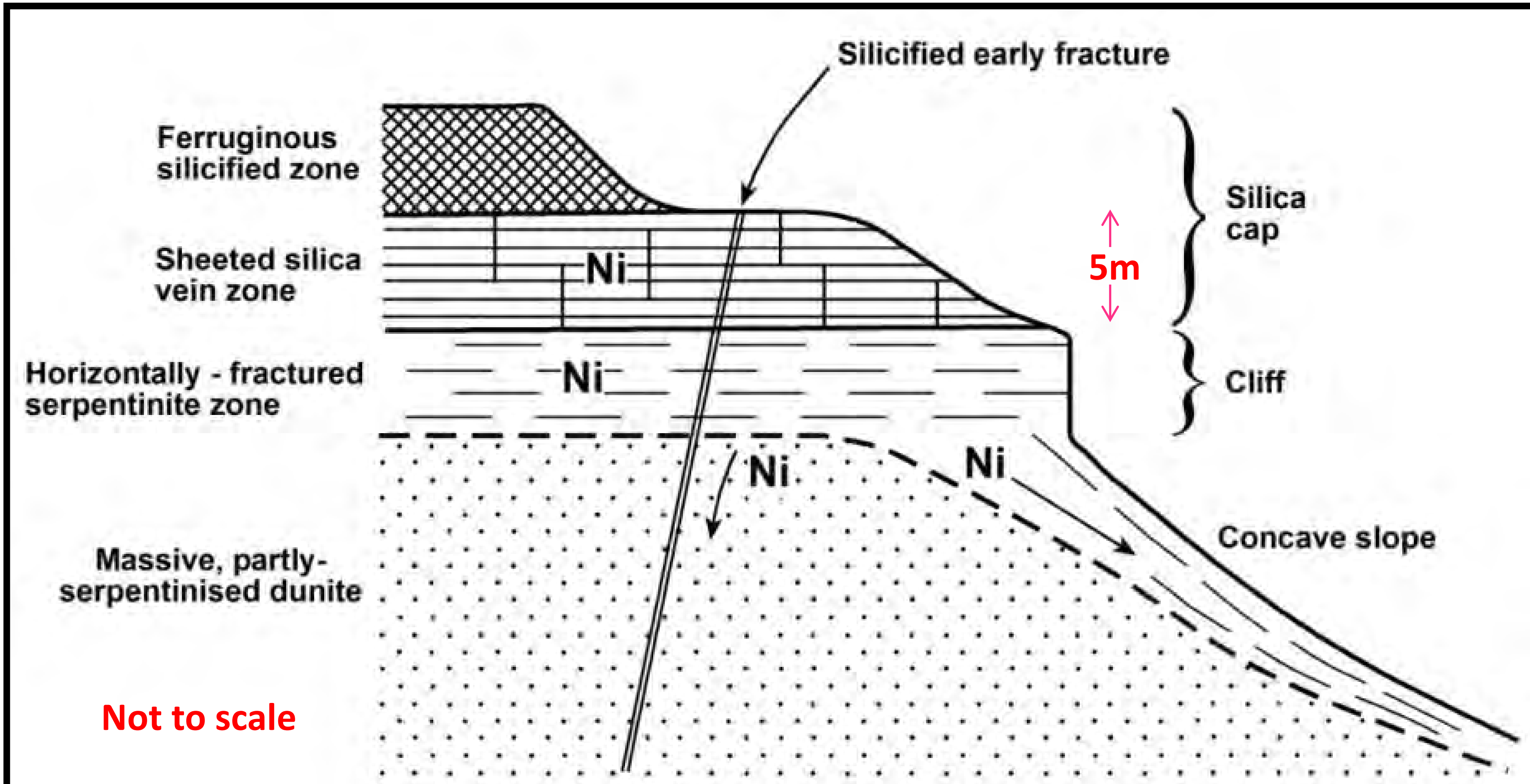
Massive silicification

Silica cap 2: Ferruginous silicified zone

Typical flat-topped, *mesa*-like, landform, Mvurwi section

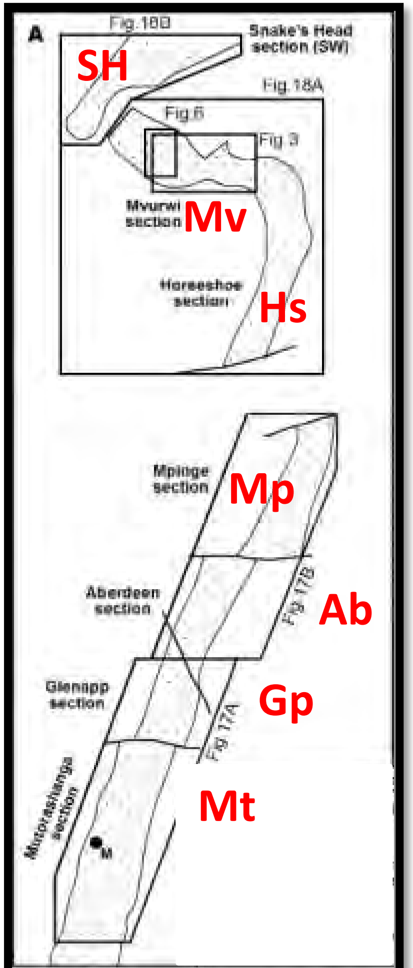


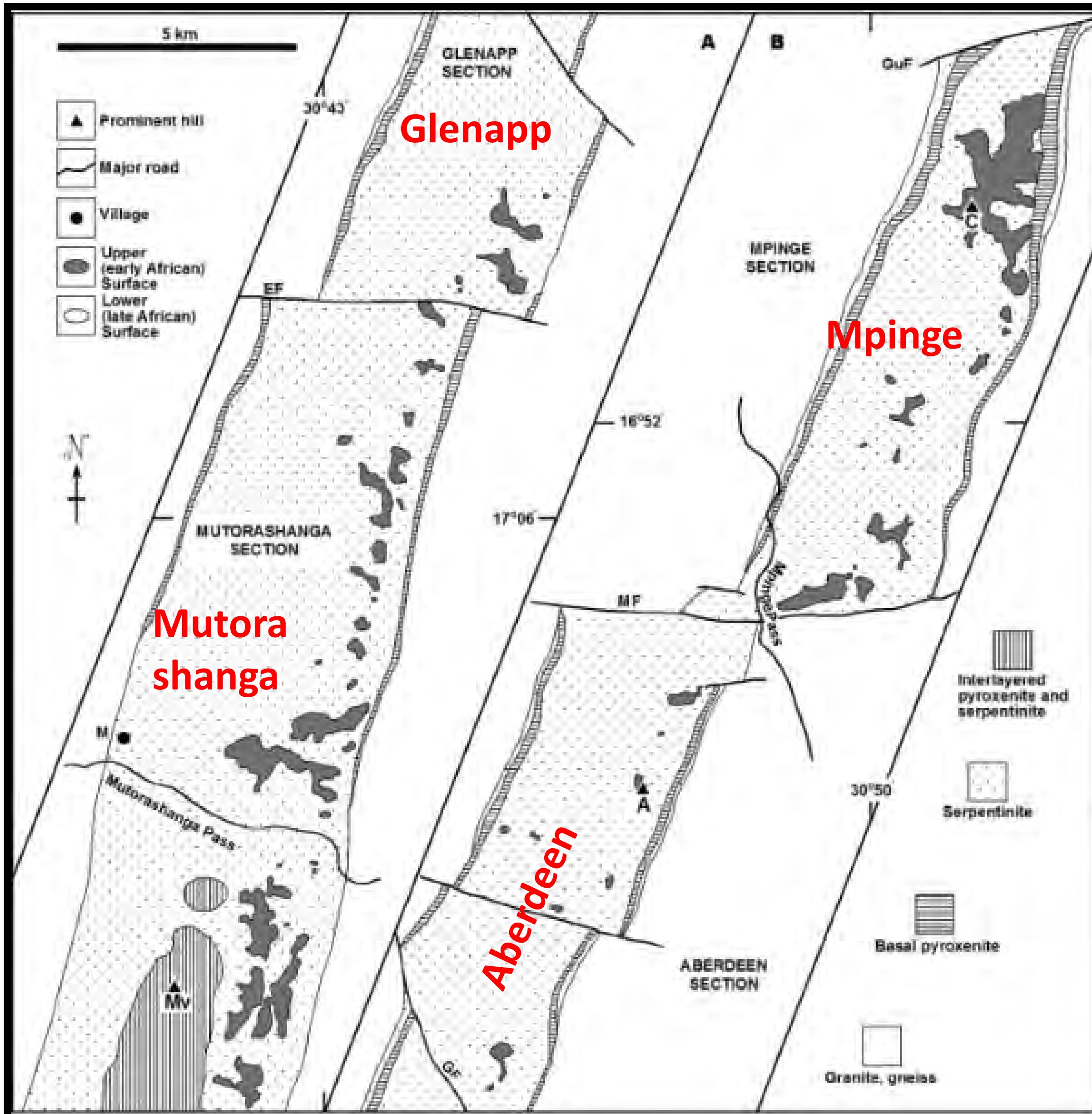
Plan of typical *mesa*, Mvurwi section



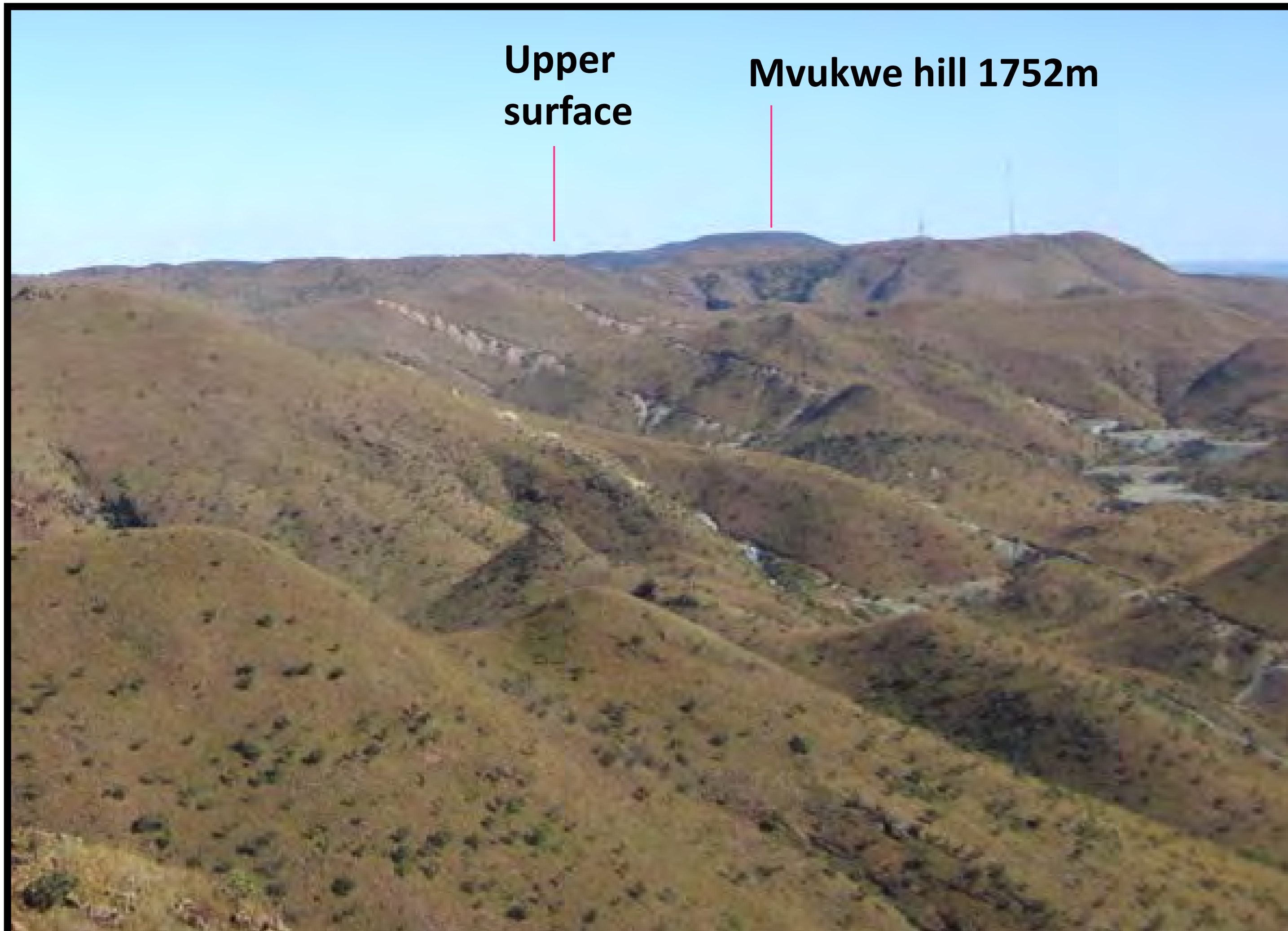
Regolith stratigraphy

3. Distribution of Erosion Surfaces

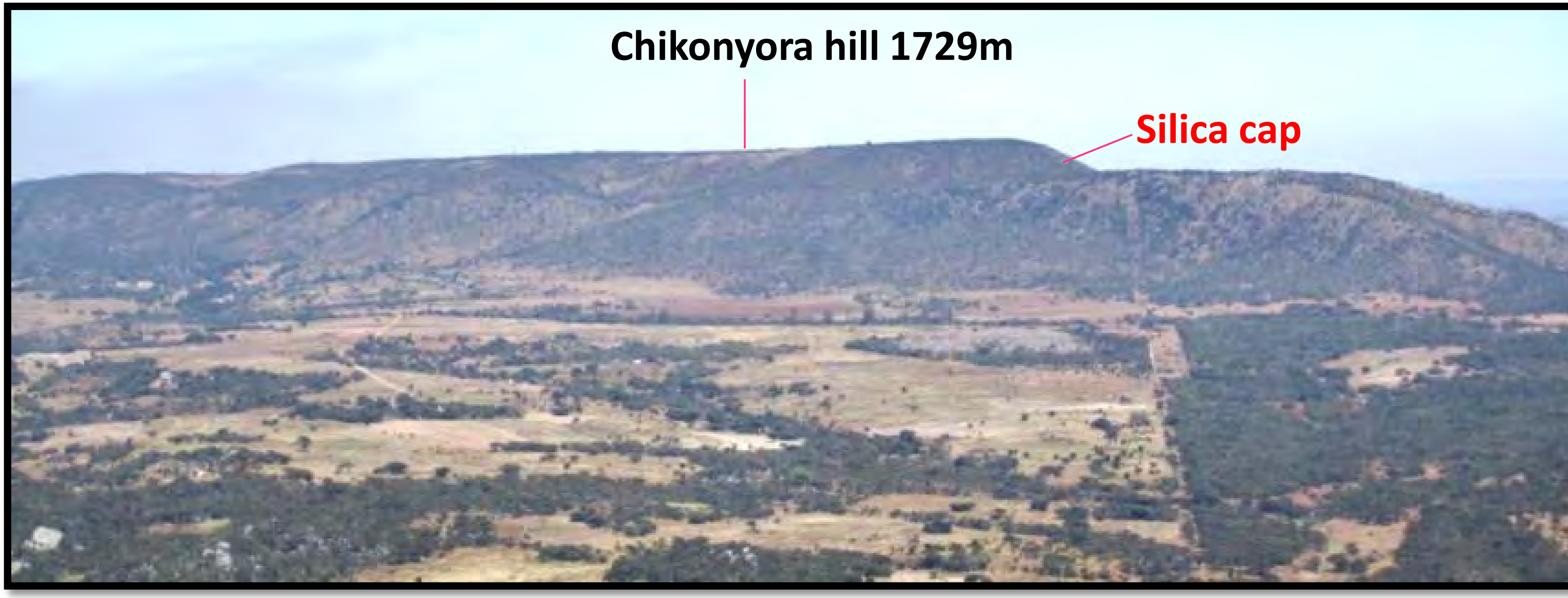




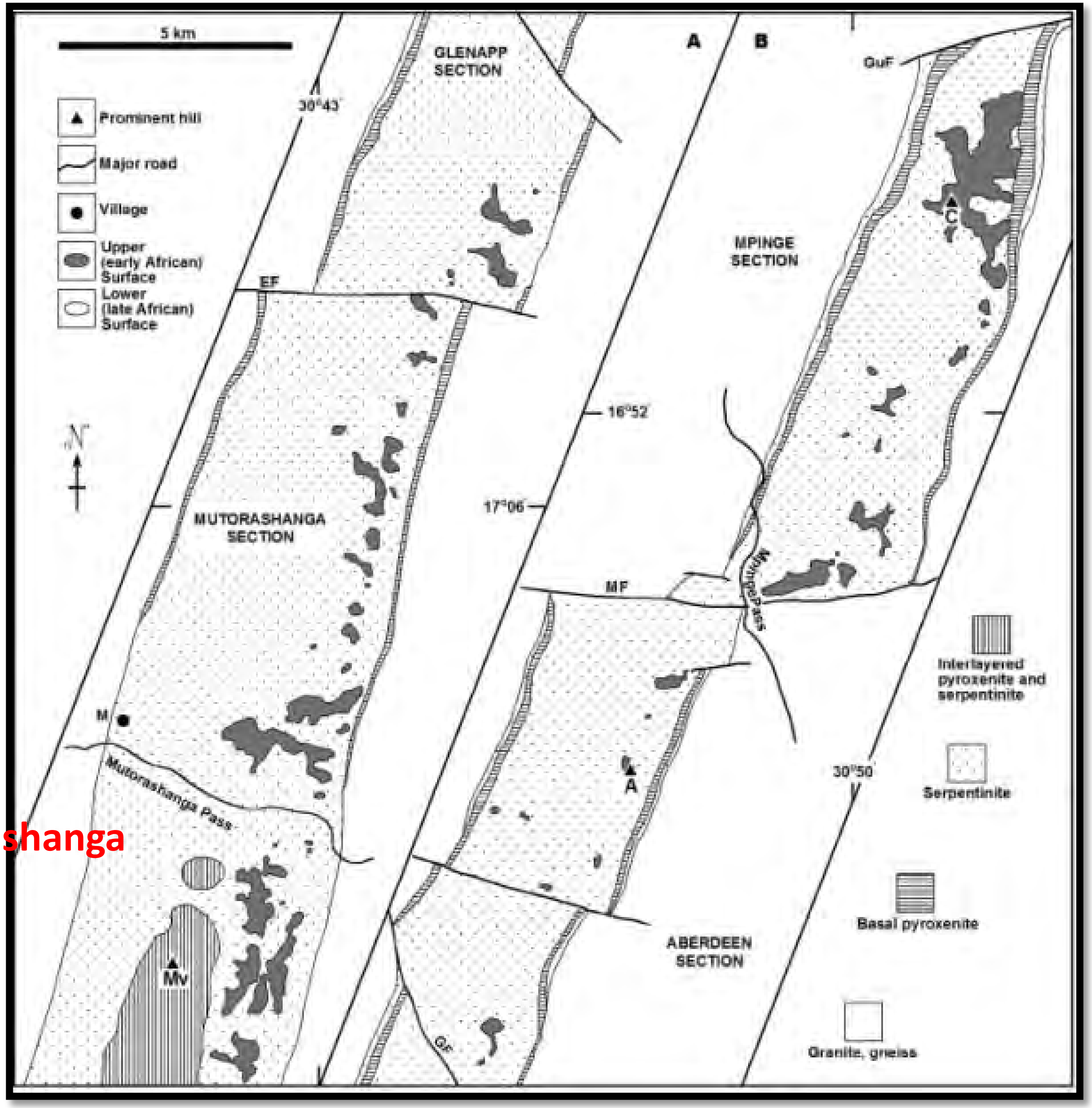
Upper erosion surface, Mutorashanga – Mpinge sections



Upper erosion surface at Mutorashanga: view south



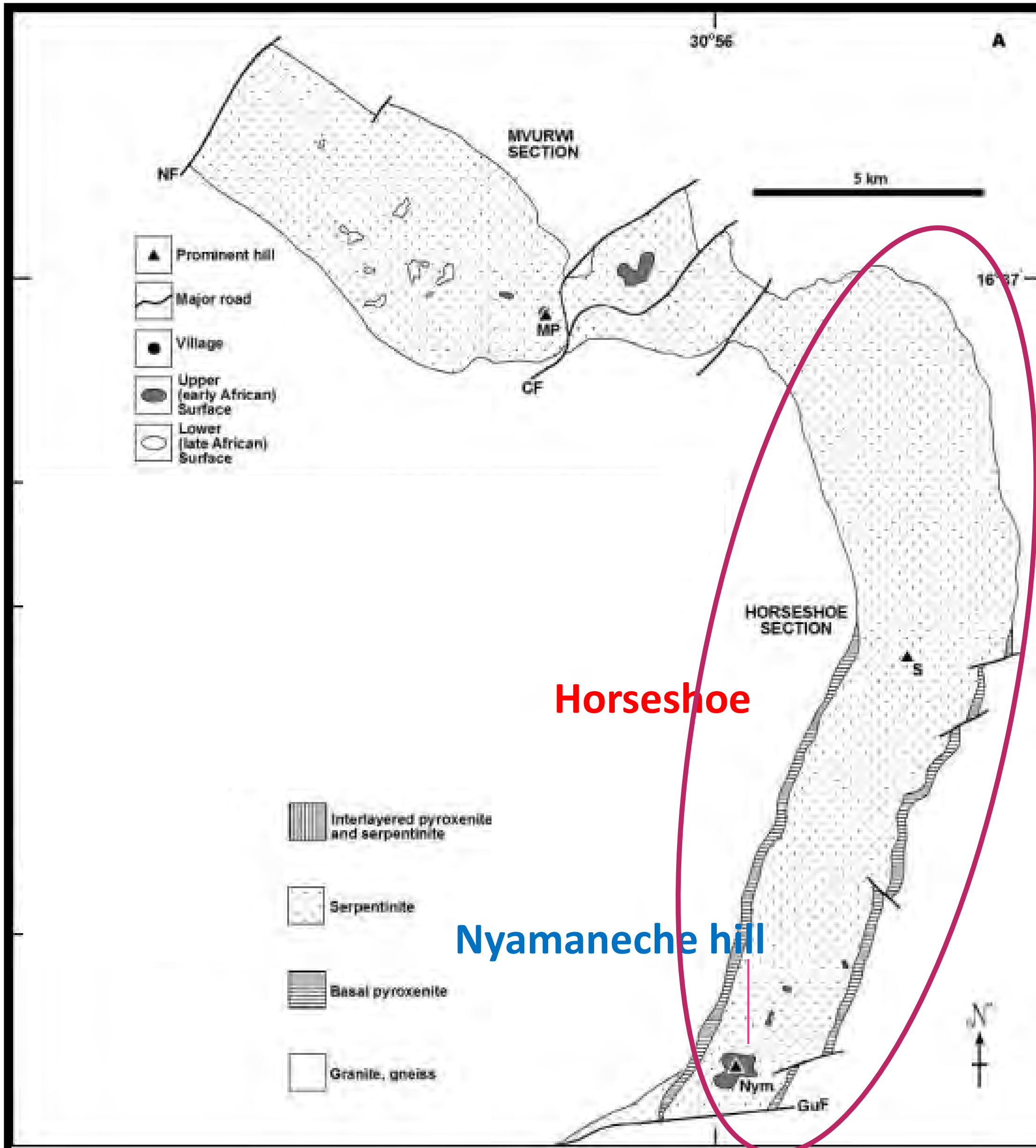
Upper erosion surface at Mpinge: view west



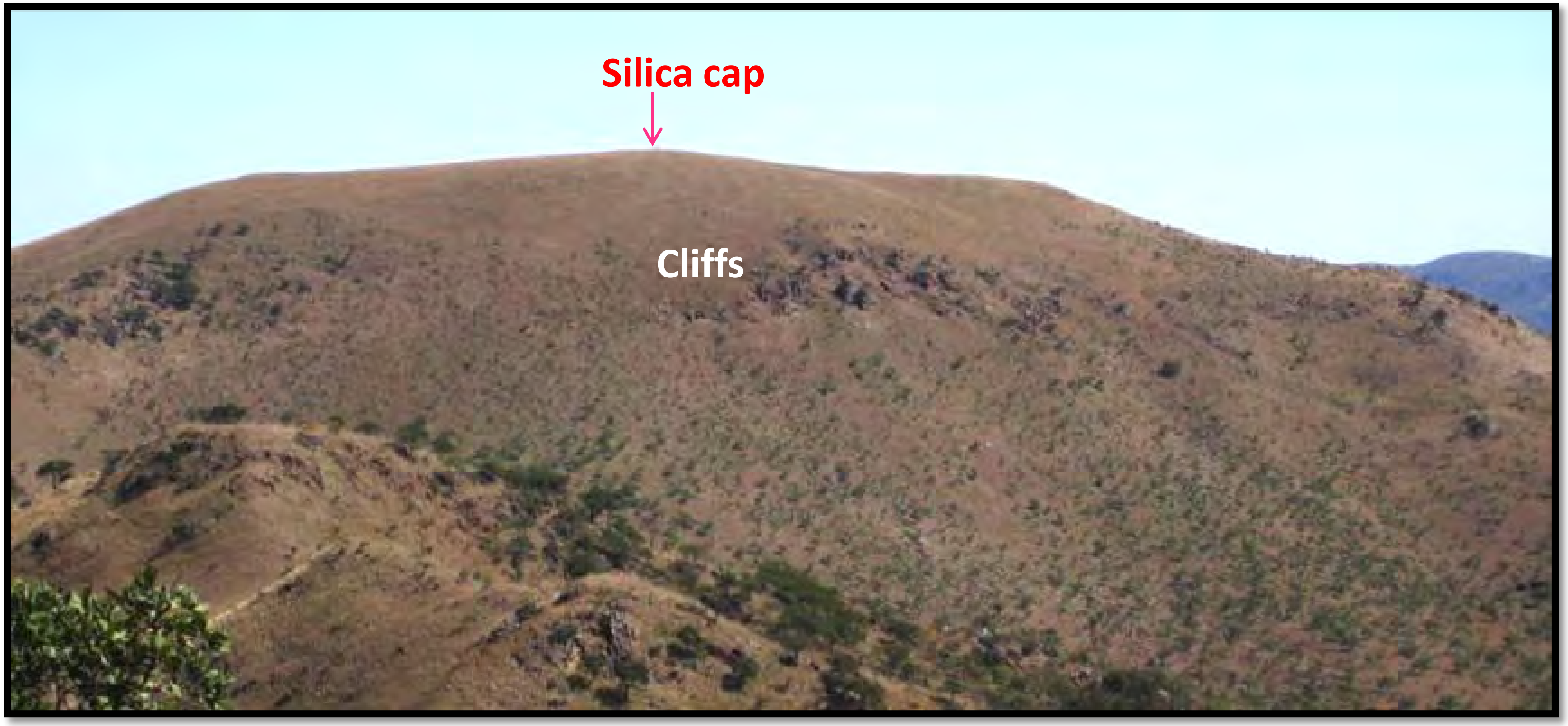
Mpinge

Mutorashanga

Upper erosion surface, Mutorashanga – Mpinge sections

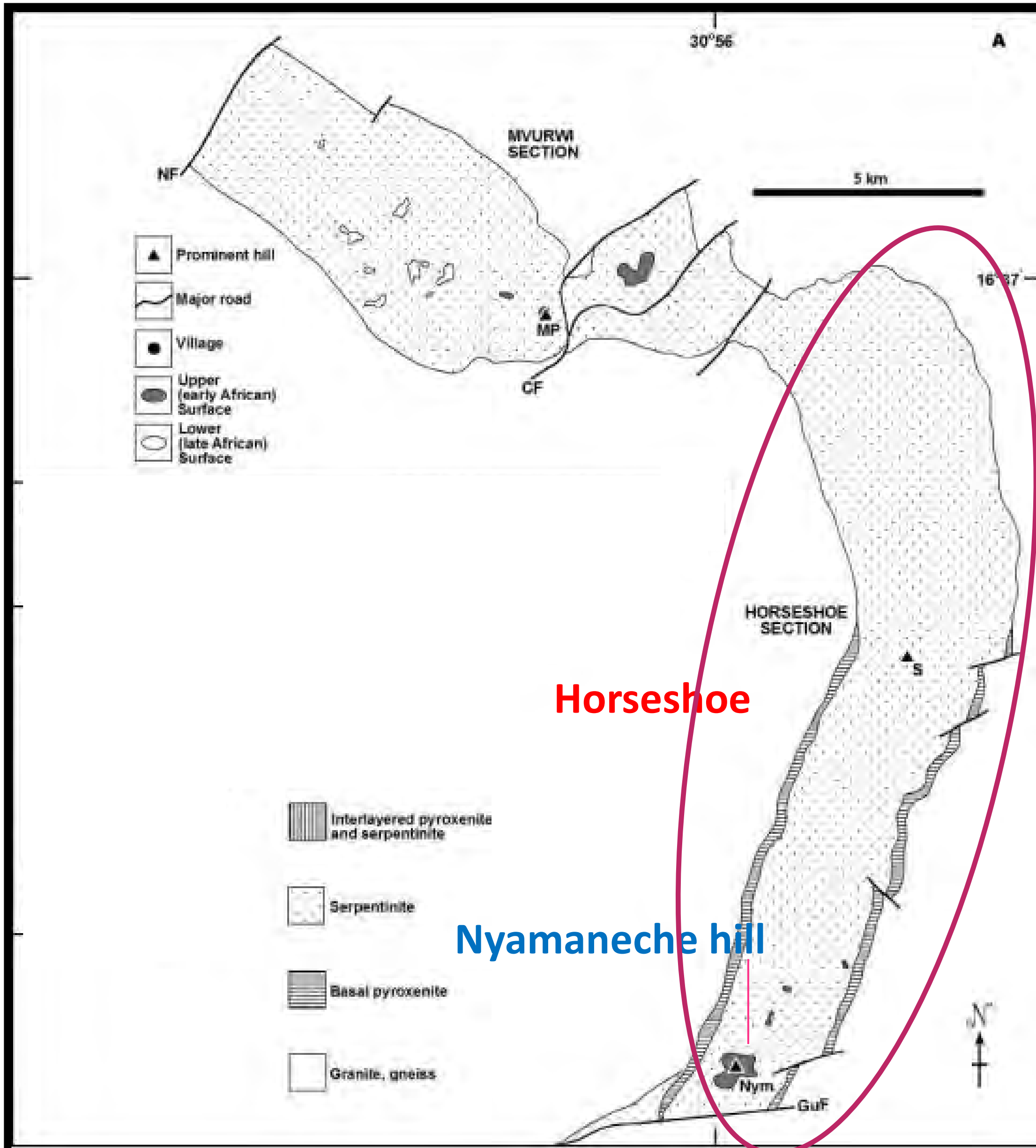


Upper erosion surface, Horseshoe section



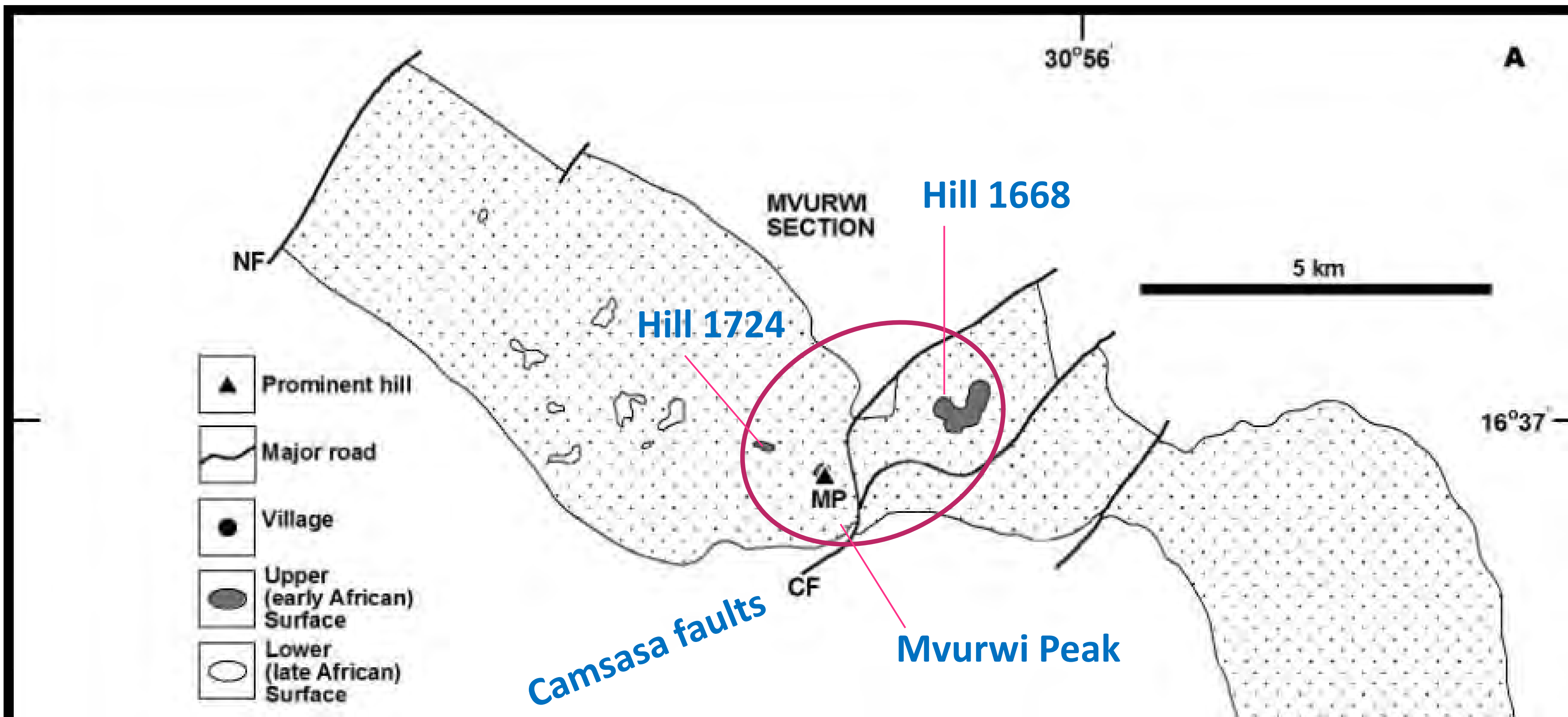
Upper erosion surface, Nyamaneche hill

**Upper erosion surface, Horseshoe section,
cliffs at 1700 m, 2 km north of Nyamaneche hill**



Upper erosion surface, Horseshoe section

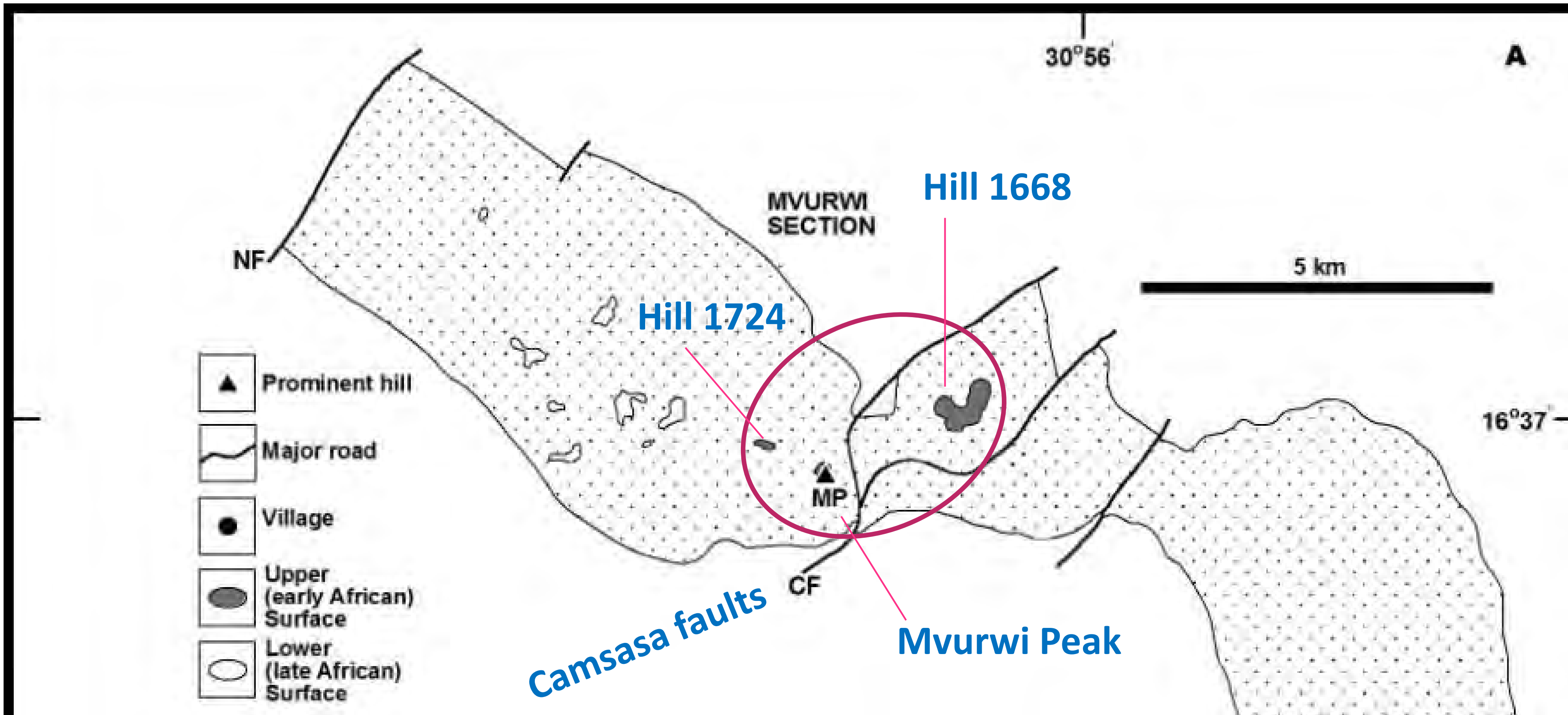
Mvurwi section, view north



Upper erosion surface, Mvurwi section east

**Upper erosion surface, Mvurwi section east,
silica cap rubble on Mvurwi Peak**

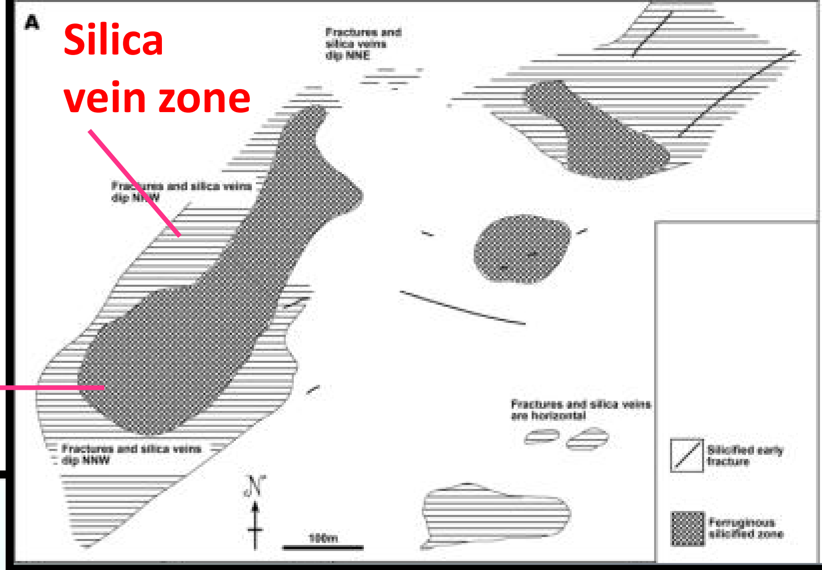
Mvurwi section, view north

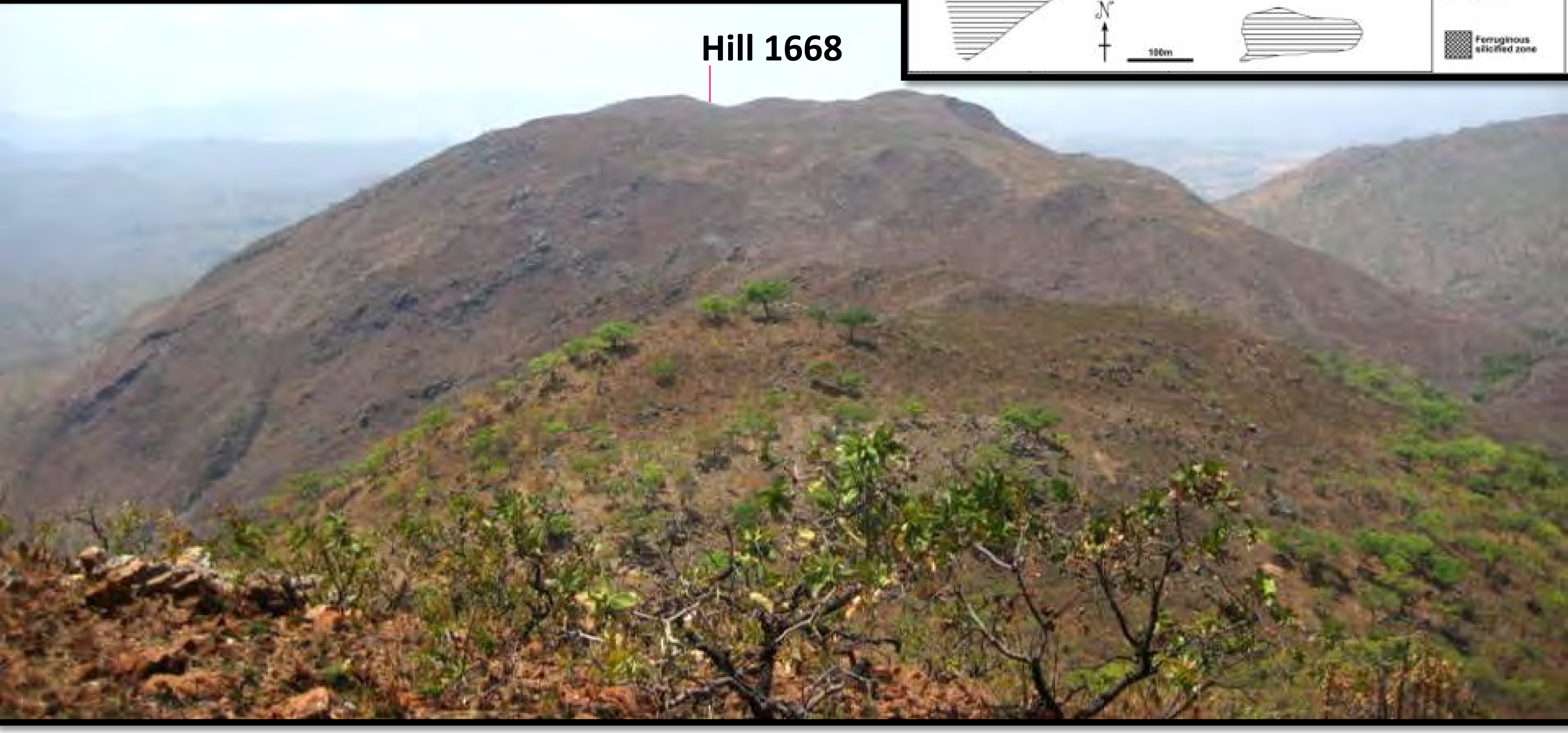


Upper erosion surface, Mvurwi section east

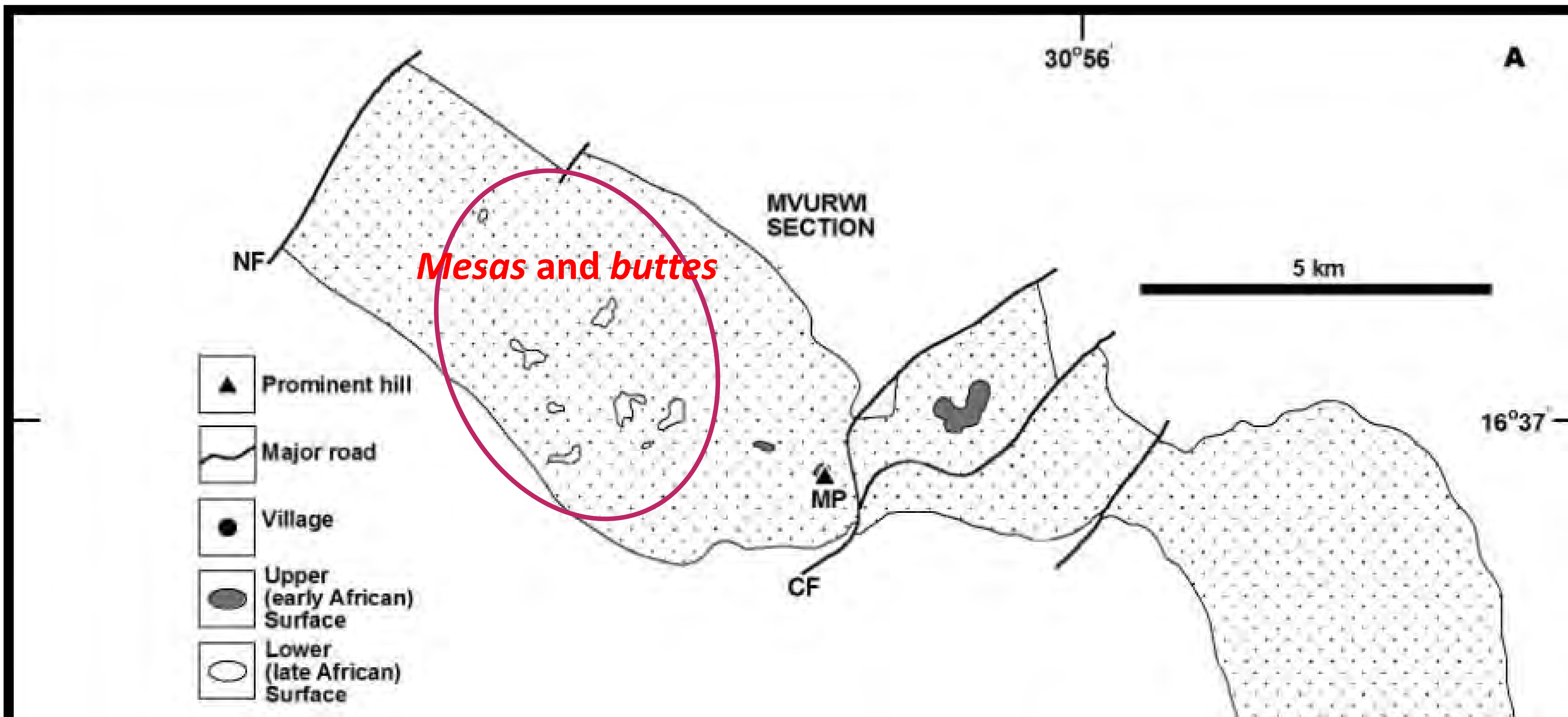
Upper erosion surface, Mvurwi section east, Hill 1668

Massive silicification



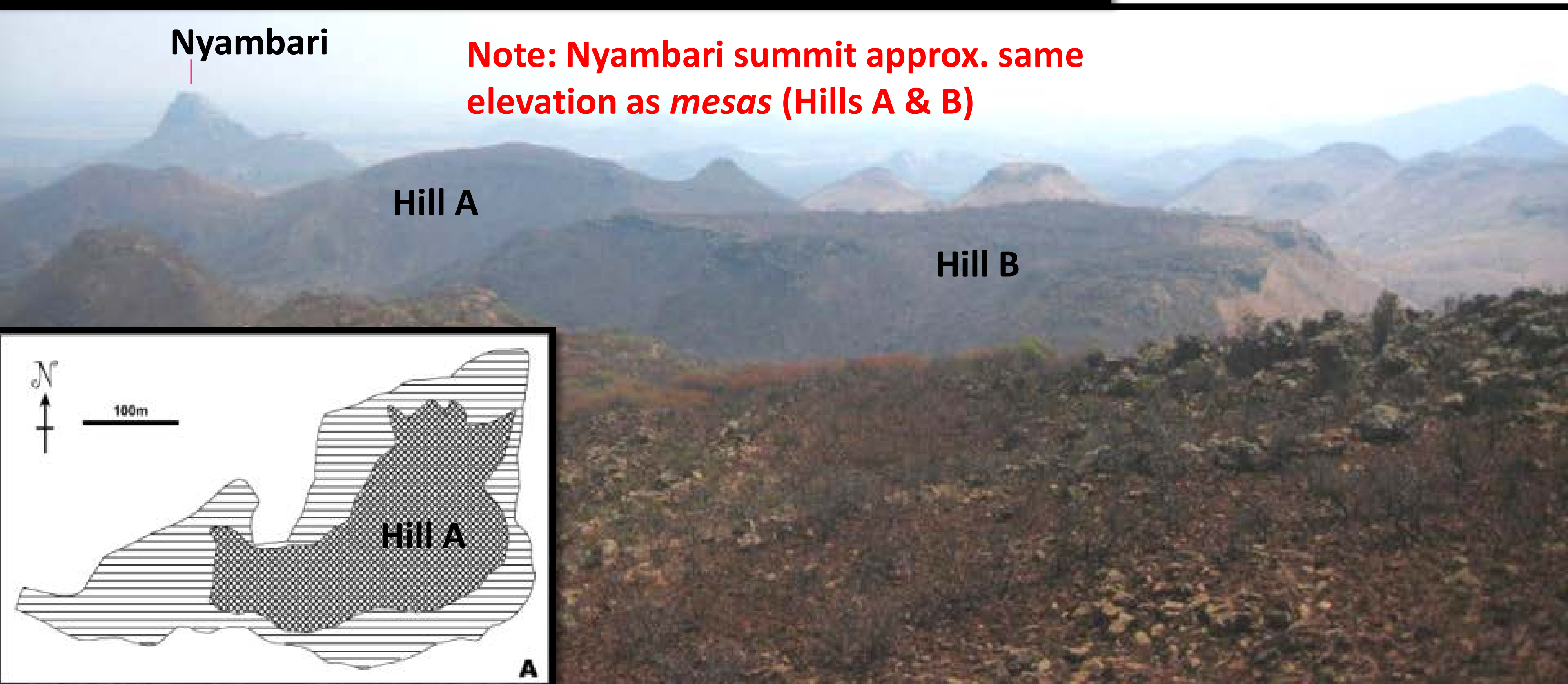


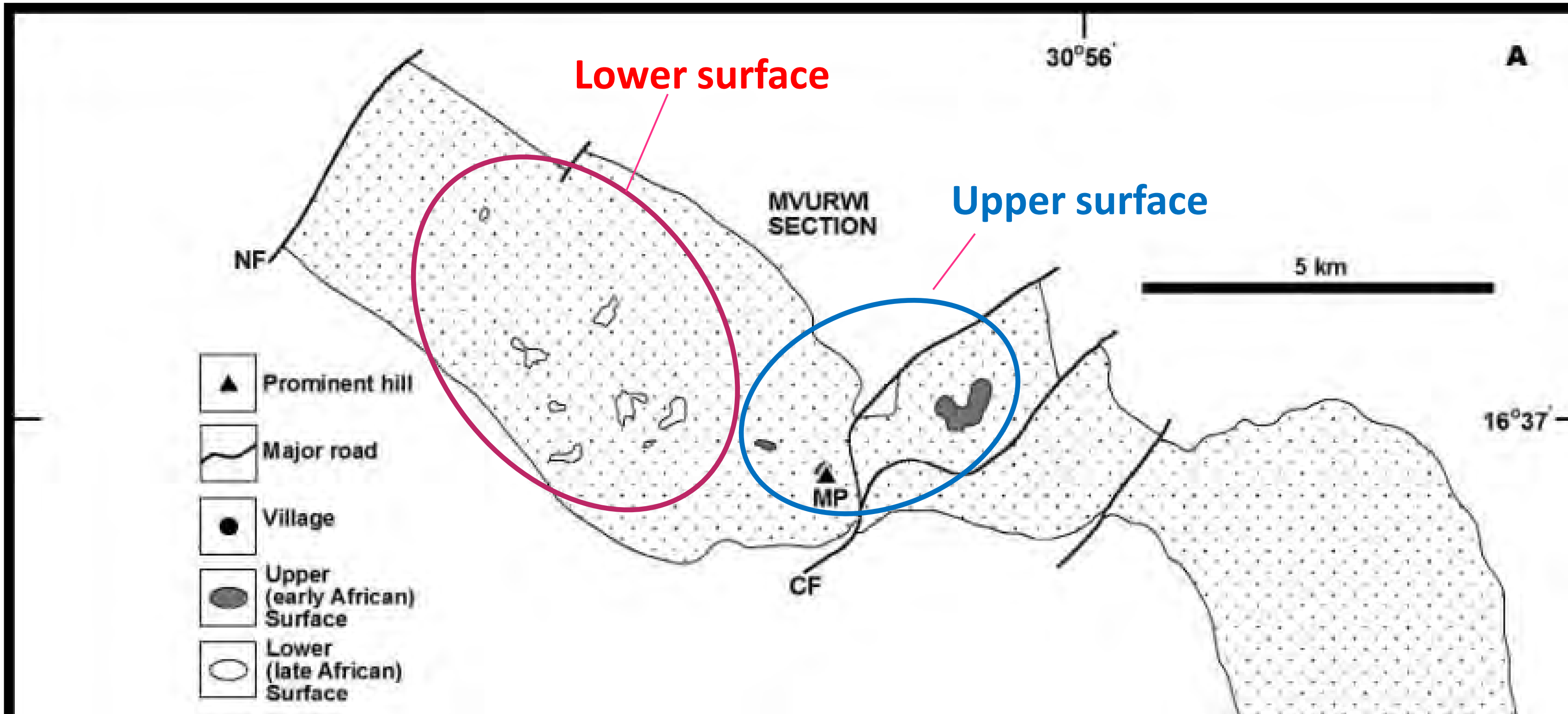
Mvurwi section, view north

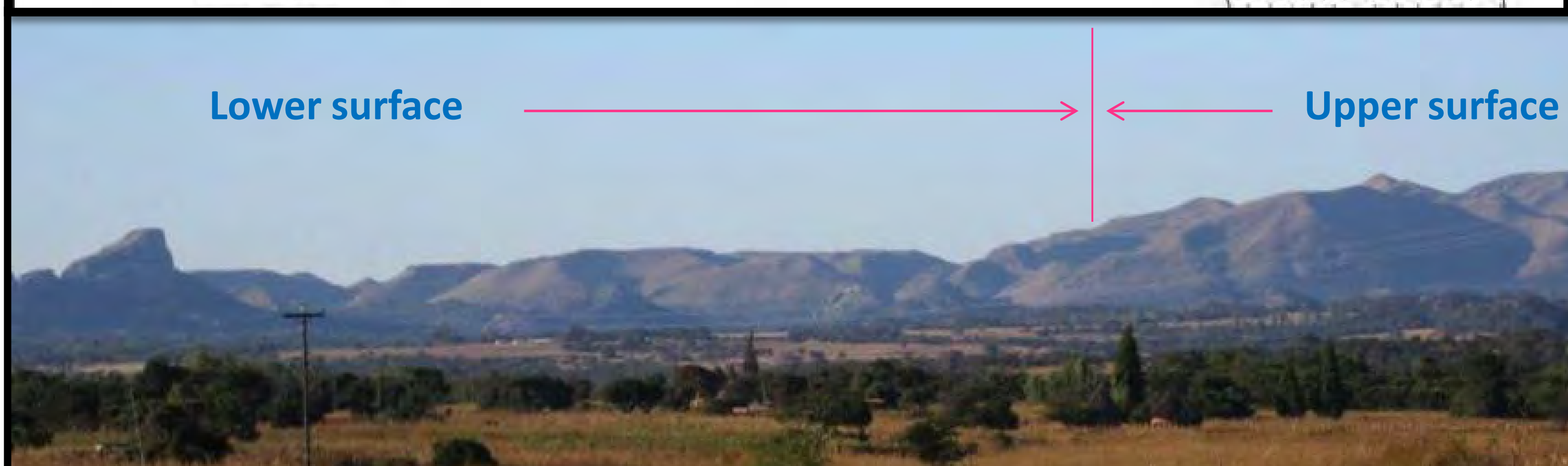


Lower erosion surface, Mvurwi section west

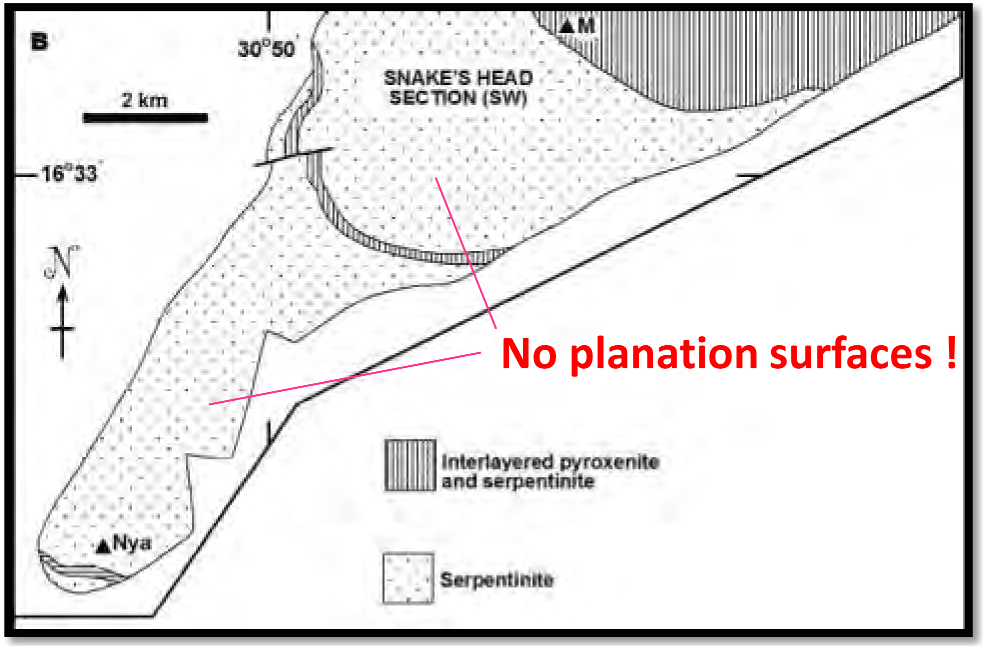
Lower erosion surface, Mvurwi section west, Views south west







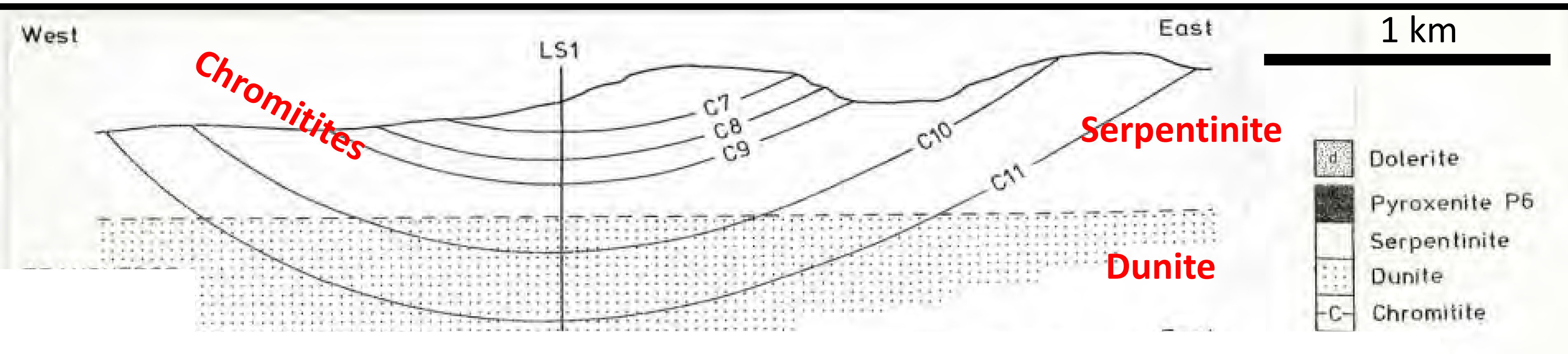
Mvurwi section: two erosion surfaces at different elevations



Snake's Head section

4. Regolith mineralogy and textures

Mutorashanga chromite mining area, ca. 1950s, viewed towards the west



Mutorashanga chromite mining area, transverse vertical section: depth of serpentinised zone

Blocky, ‘sculpted’, partially serpentinised dunite, Mvurwi section (with ca. 50% fresh olivine)

Massive, weakly serpentinised dunite, near Makura, Snake's Head section (with > 75% fresh olivine)

Regolith – mineralogy and textures

- **Sheeted silica vein zone**

↑

- **Horizontally-fractured serpentinites**

↑

- **Massive serpentinite protolith**
  - primary olivine, chromite, with adcumulus textures
  - secondary serpentine (chrysotile), magnetite, red-brown goethite.

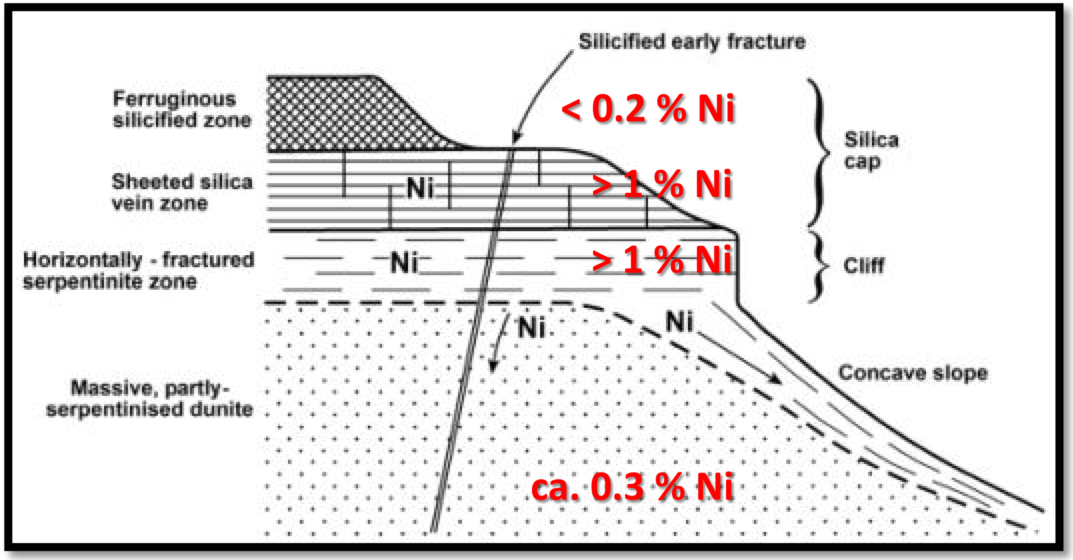
↑

loss of primary minerals and textures
increase in chrysotile and goethite abundance

↑

Sheeted silica vein zone: Typical drusy vug

5. Regolith geochemistry: Nickel enrichments in surface/near surface samples



Typical nickel contents of major regolith units, Mvurwi section

- **Massive ferruginous silicified zone** — < 0.2 % Ni
- **Sheeted silica vein zone**
- **Horizontally-fractured serpentinite (and concave slopes)**

Significant nickel enrichments: e.g., up to **3.09 % Ni > 1.60 m**, **1.21 % Ni > 1.0 m**, **1.02 - 2.10 % Ni > 0.6 - 1.6 m**

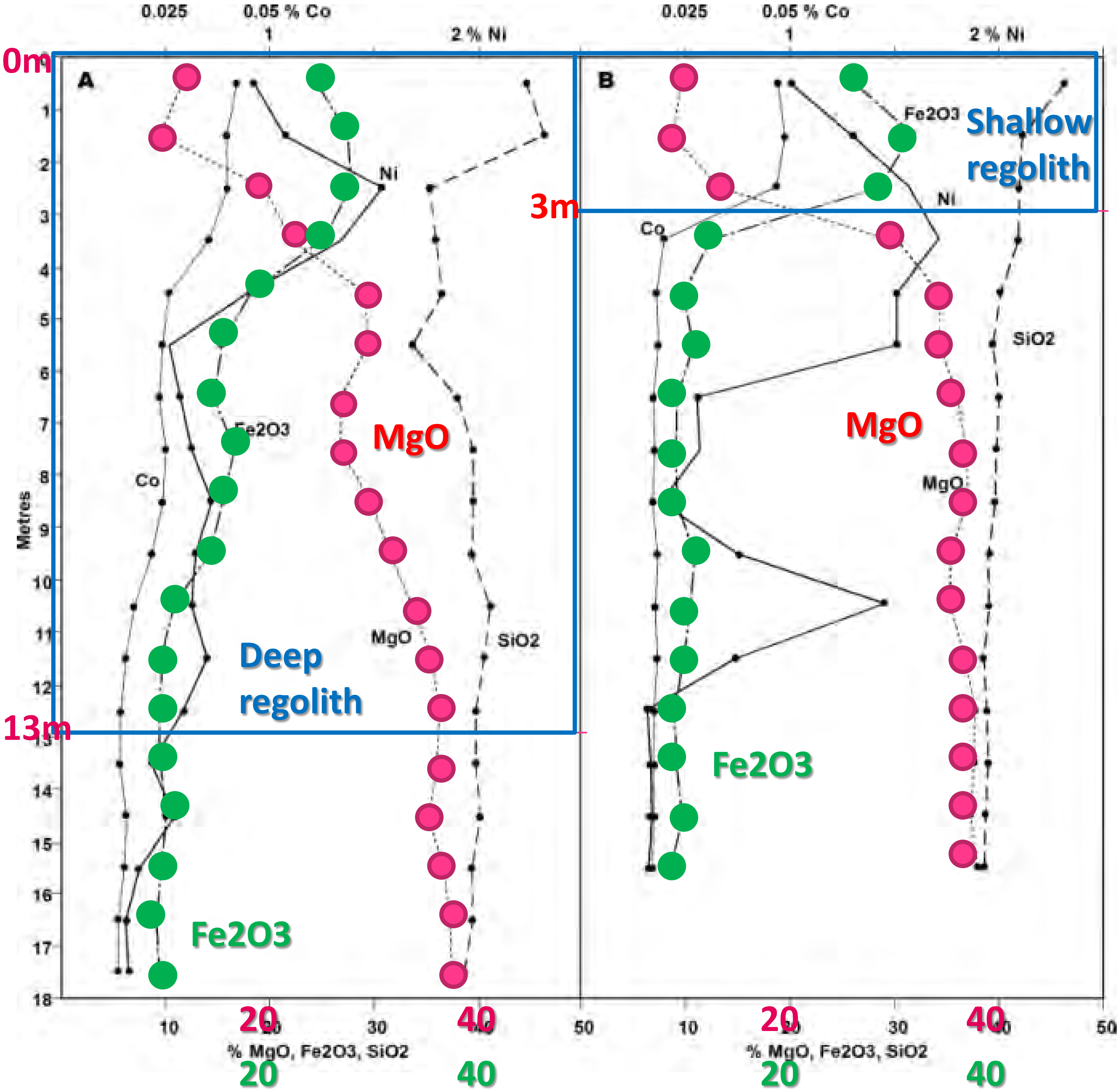
- **Massive serpentinite** — ca. 0.3 % Ni

Top: Eluvial chromite mining area

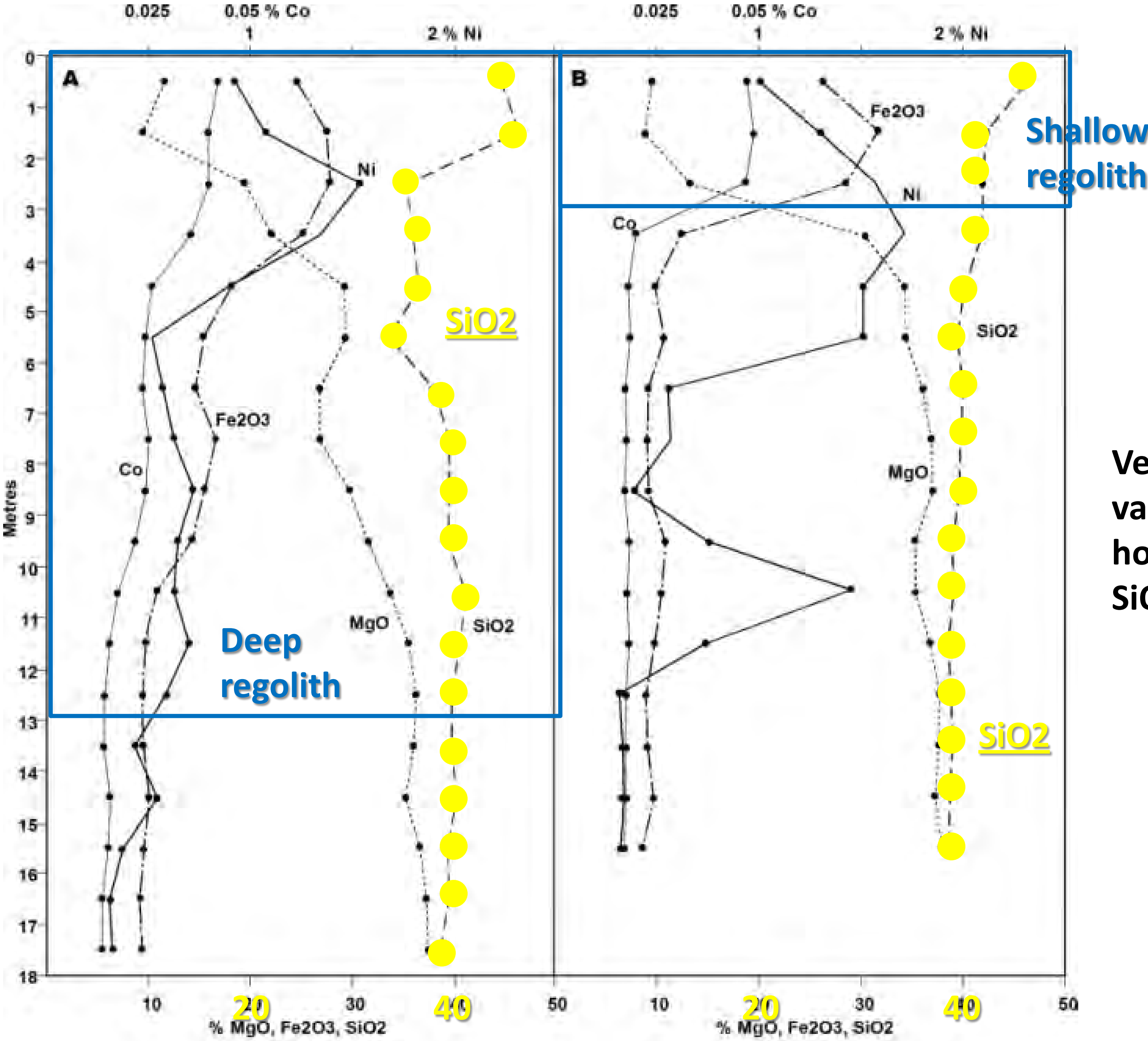
Bottom: Soil plant and slimes dam

Mpinge section, ca. 1974

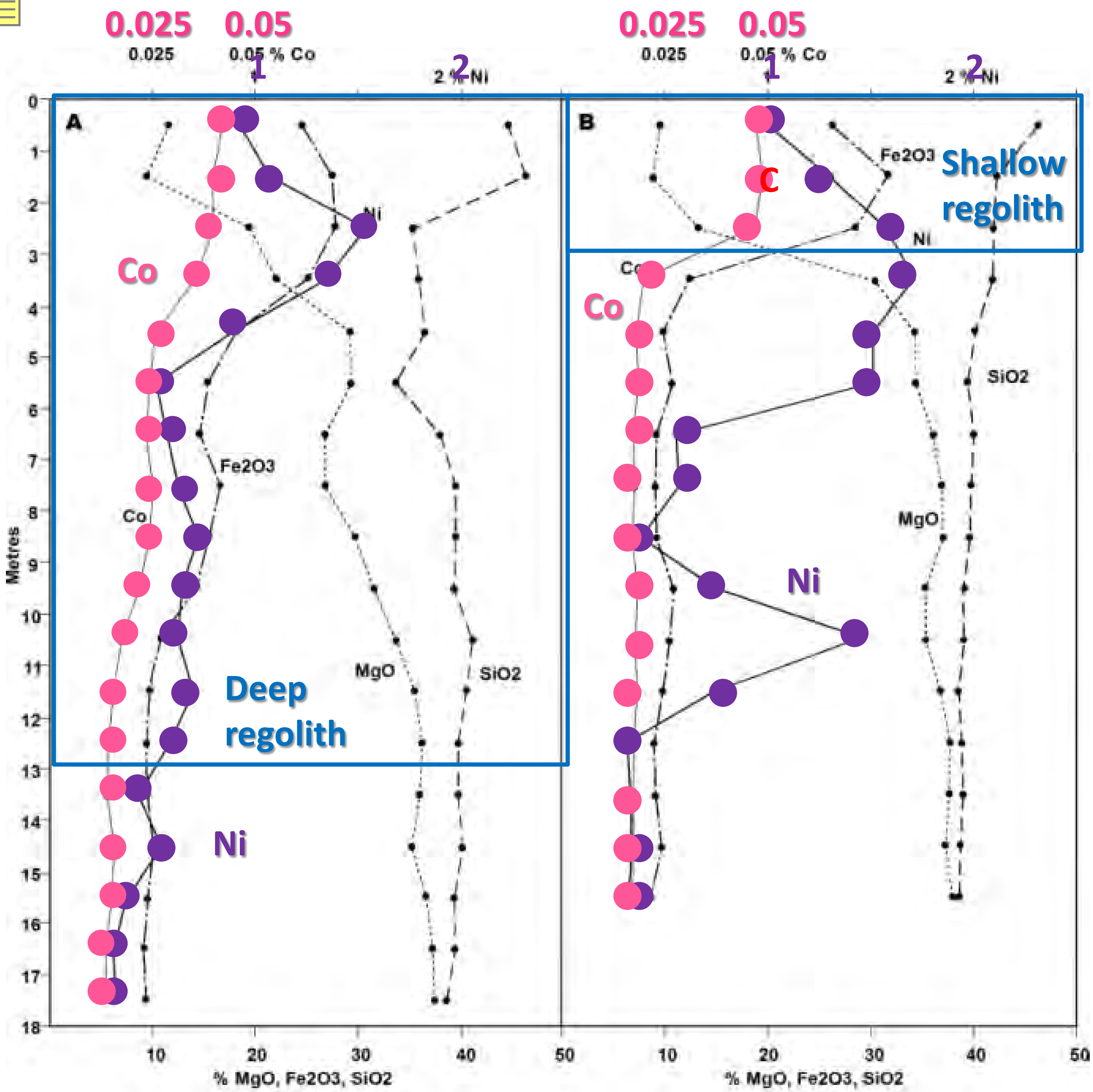
6. Regolith geochemistry: Vertical variations in Ni, Co and major /minor oxides in drill samples



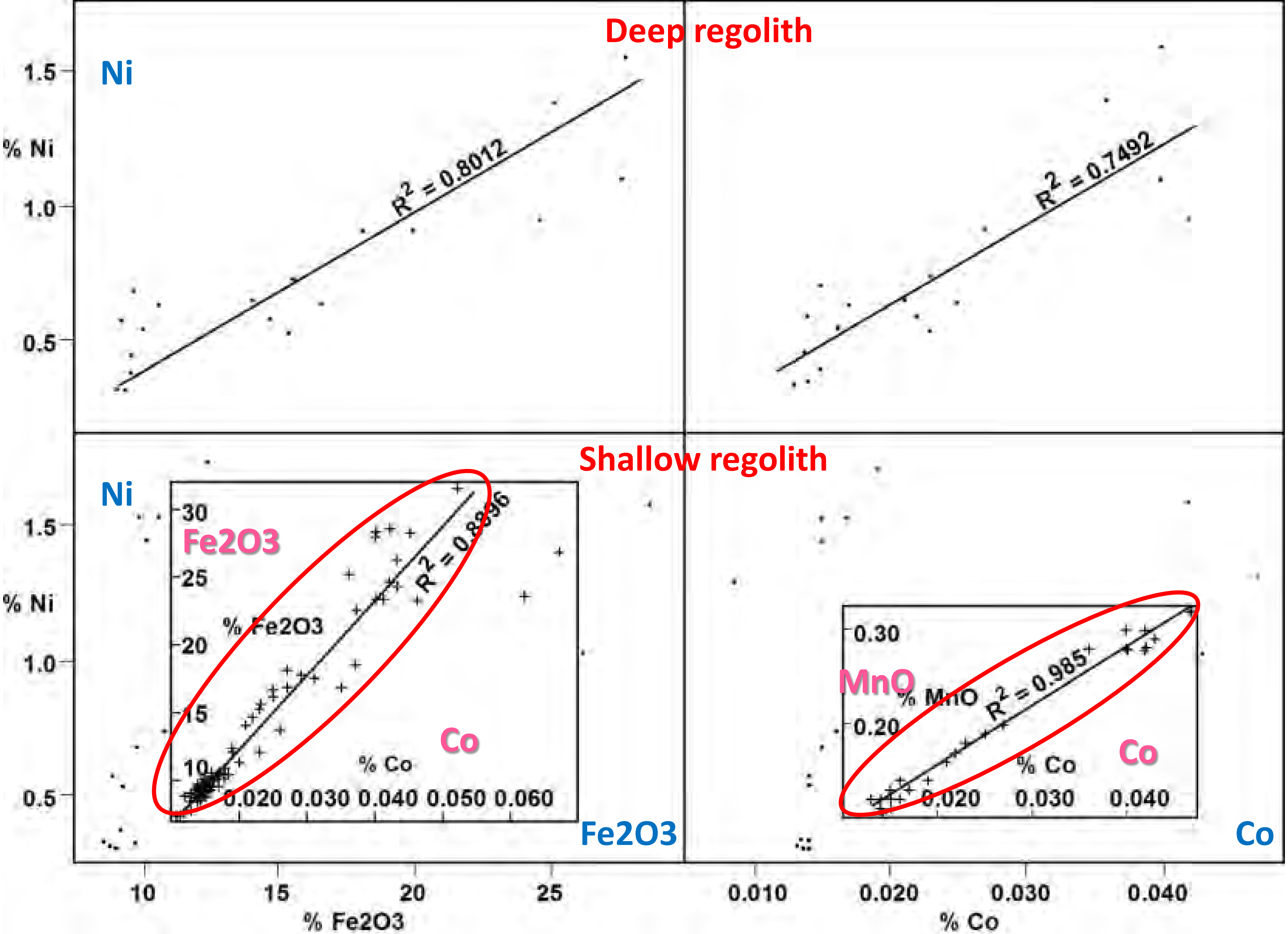
Vertical geochemical variations in two drill-holes, Shear Zone hill: MgO and Fe2O3



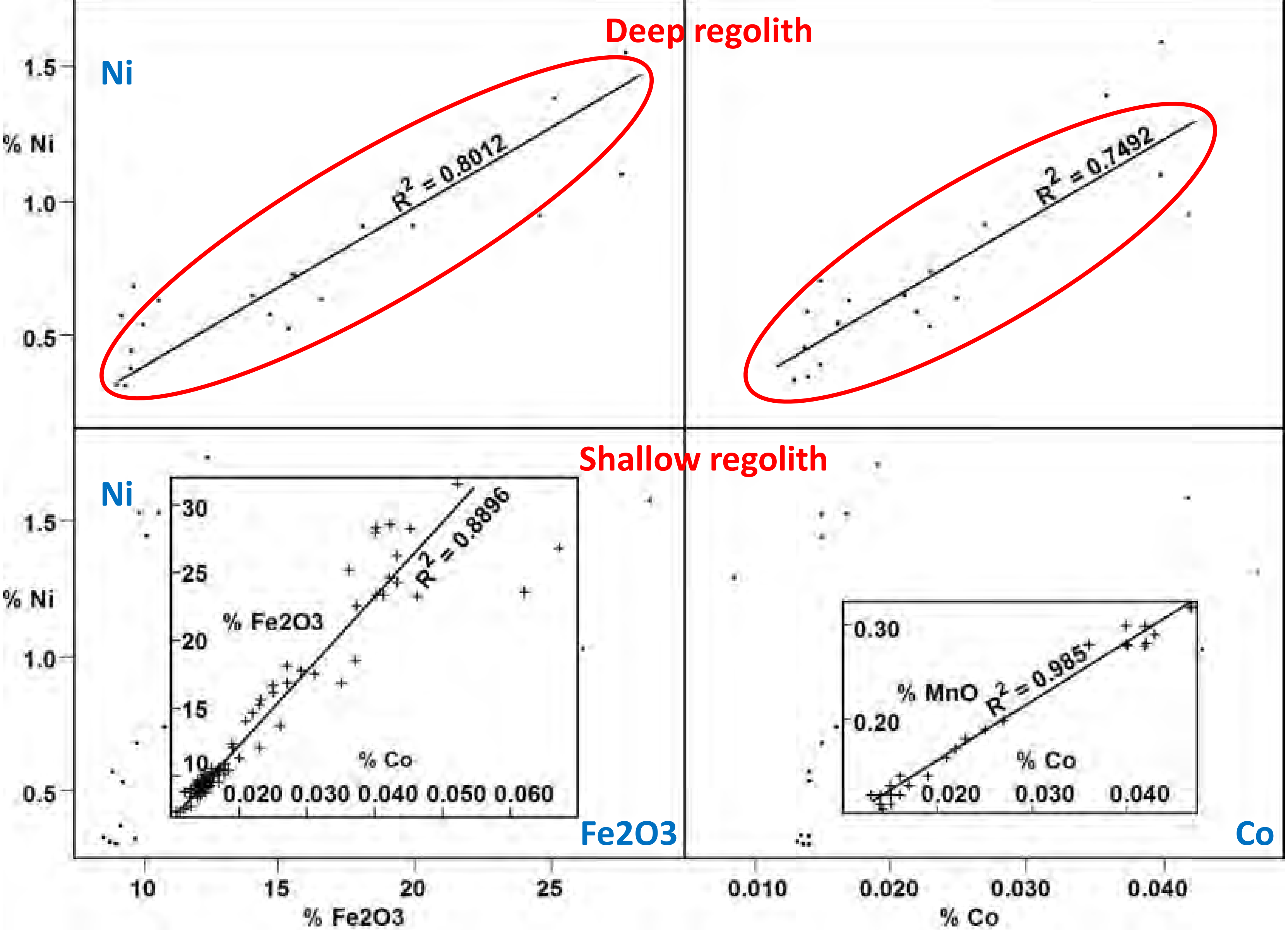
Vertical geochemical variations in two drill-holes, Shear Zone hill: SiO2



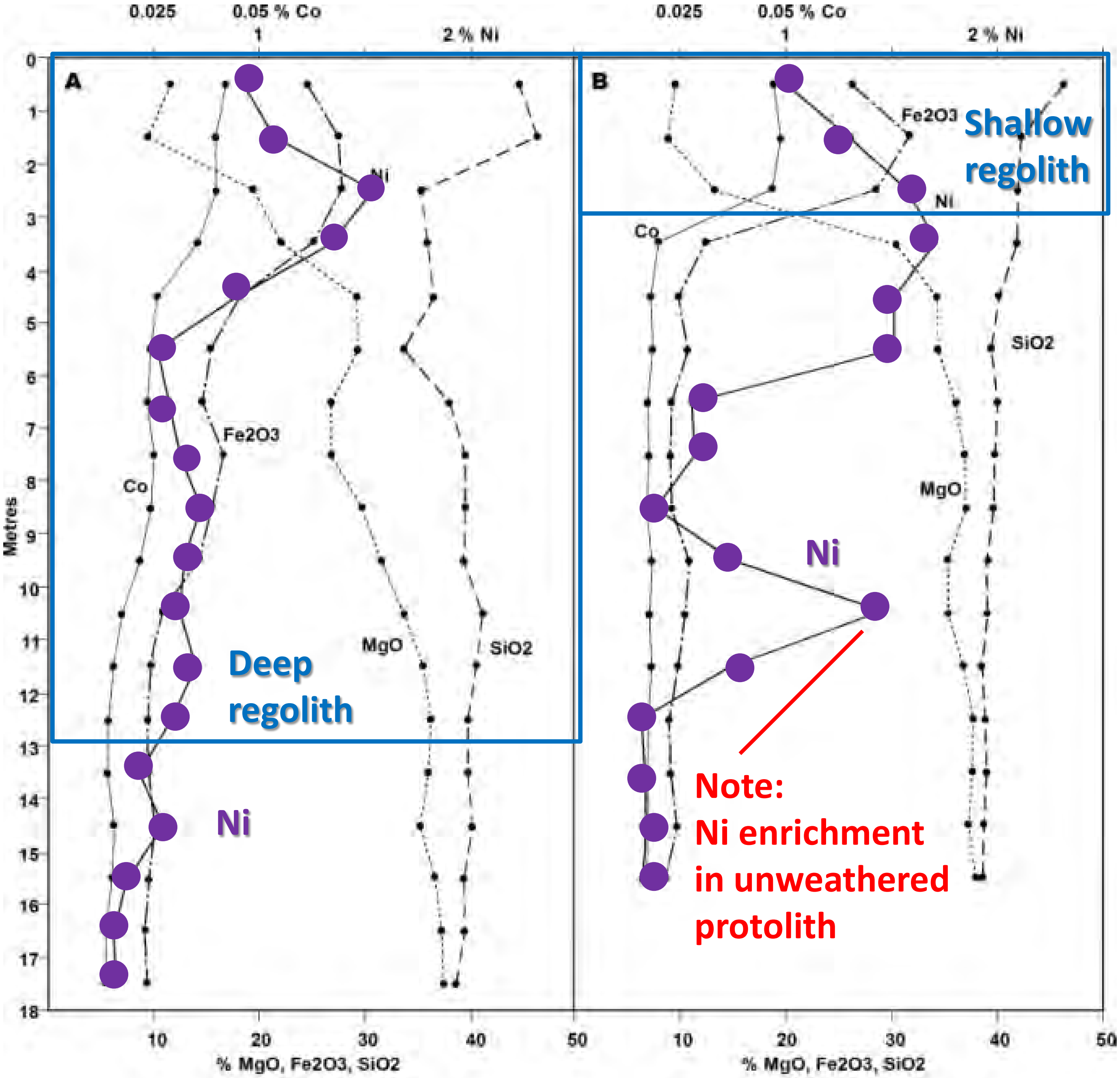
Vertical geochemical variations in two drill-holes, Shear Zone hill: Ni



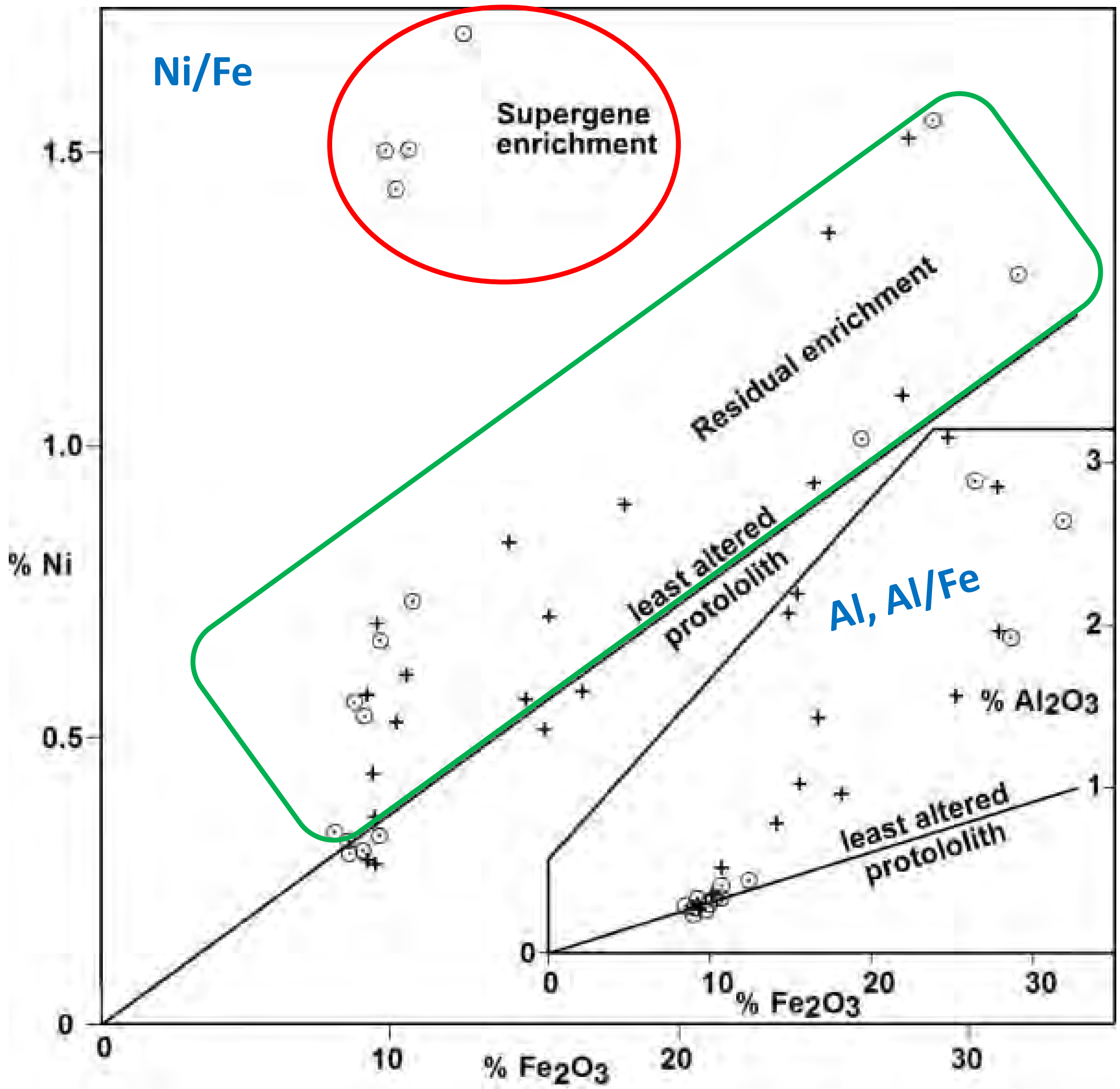
Geochemical variations in two drill-holes, Shear Zone hill: Ni vs. Fe2O3 & Co, Fe2O3 vs. Co, and MnO vs. Co



Geochemical variations in two drill-holes, Shear Zone hill: Ni vs. Fe2O3 & Co, Fe2O3 vs. Co, and MnO vs. Co

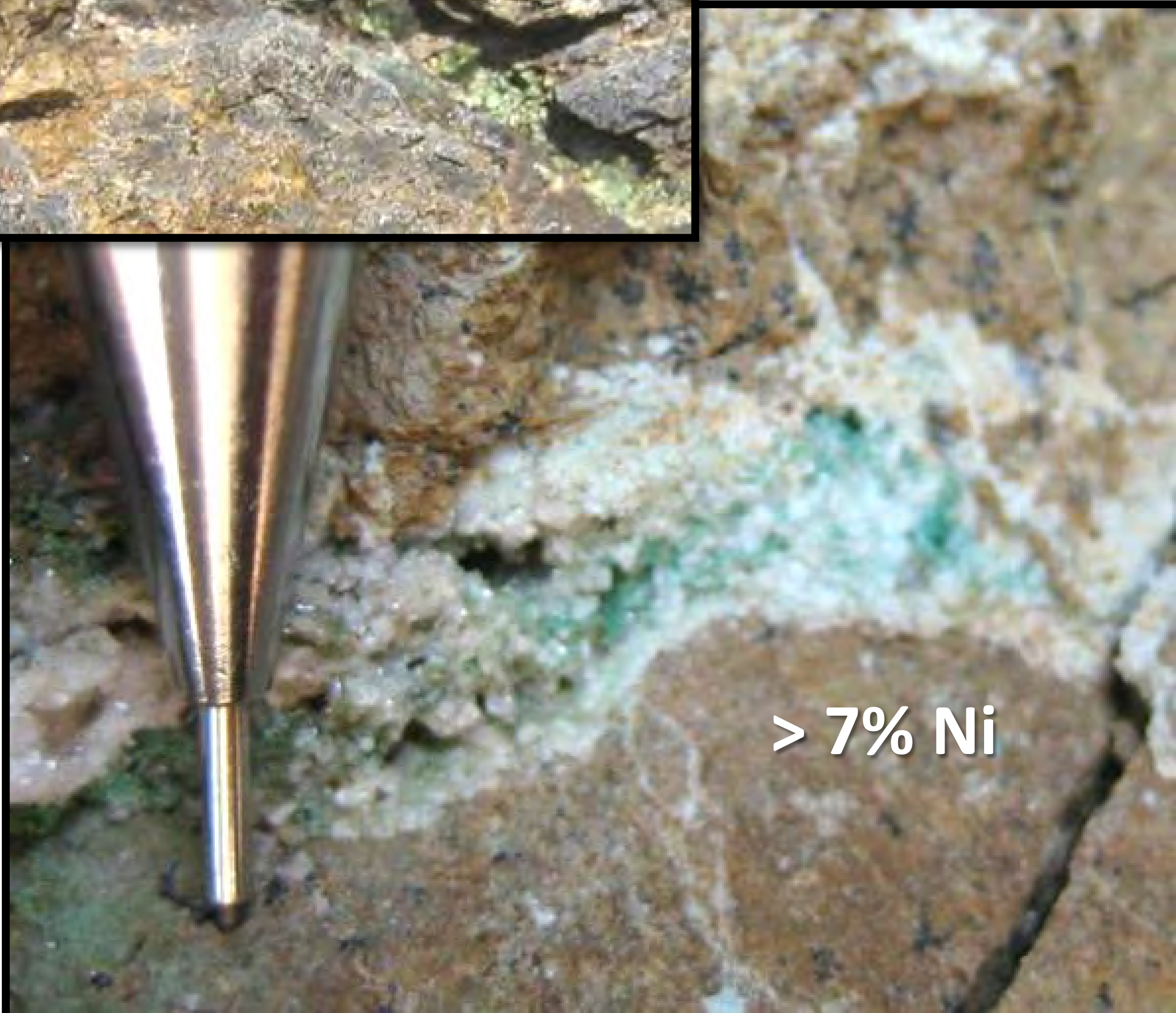


Vertical geochemical variations in two drill-holes, Shear Zone hill: Ni

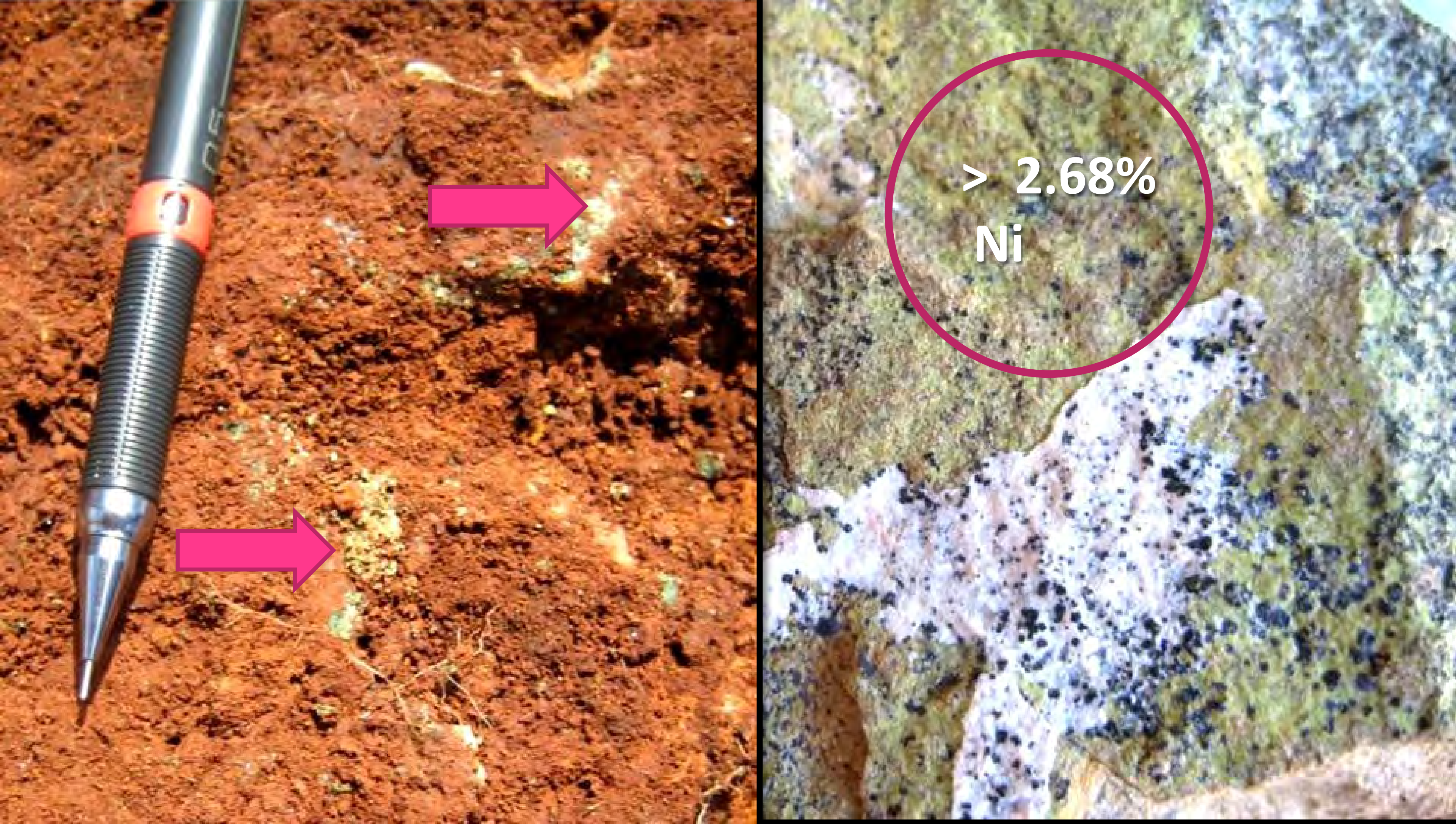


Geochemical variations in two drill-holes, Shear Zone hill: Ni vs. Fe2O3, and Al2O3 vs. Fe2O3

7. Probable mineralogy of nickel enrichments



Discrete, macroscopic, green, Ni-rich minerals in joints/ fractures



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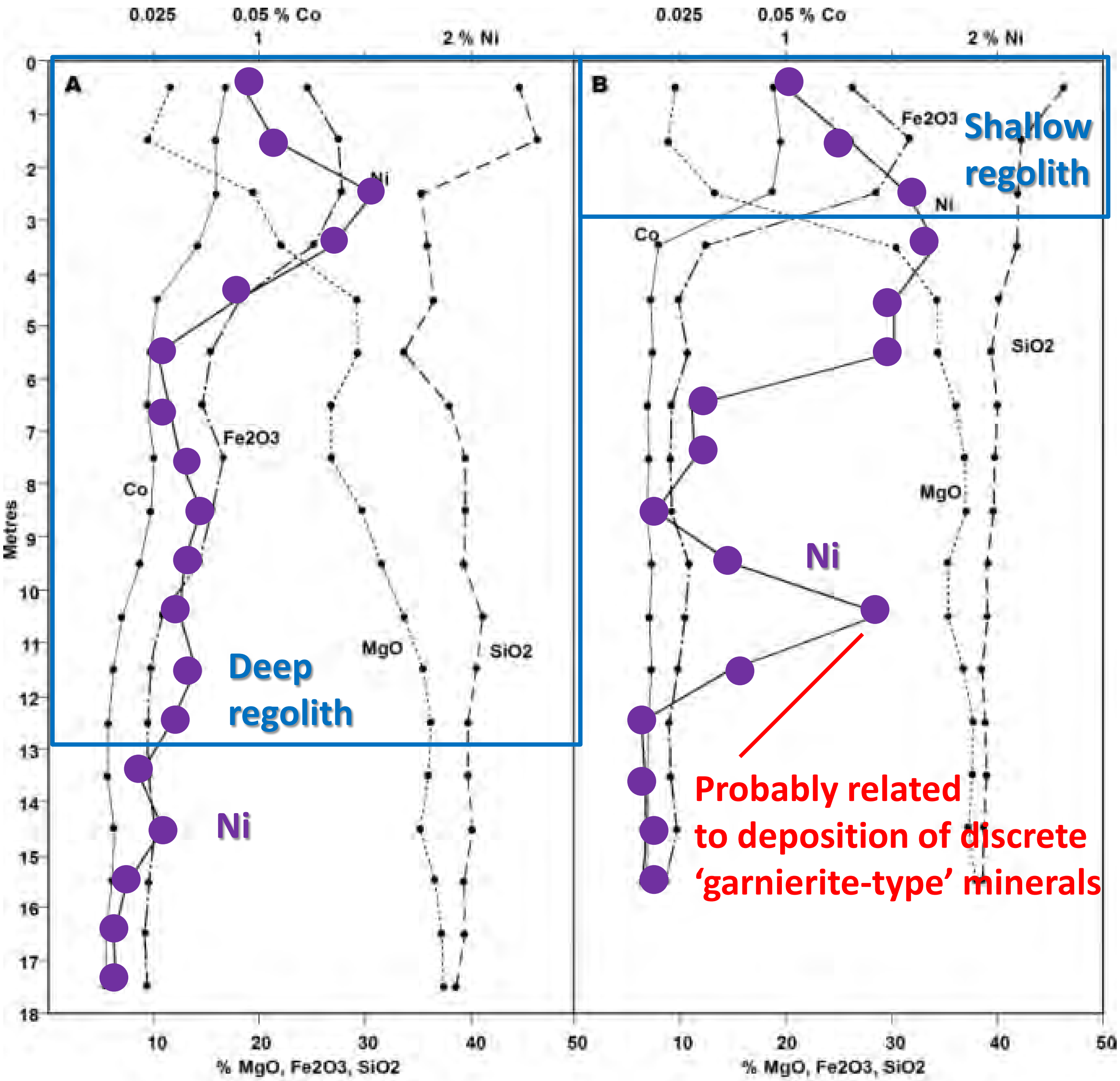
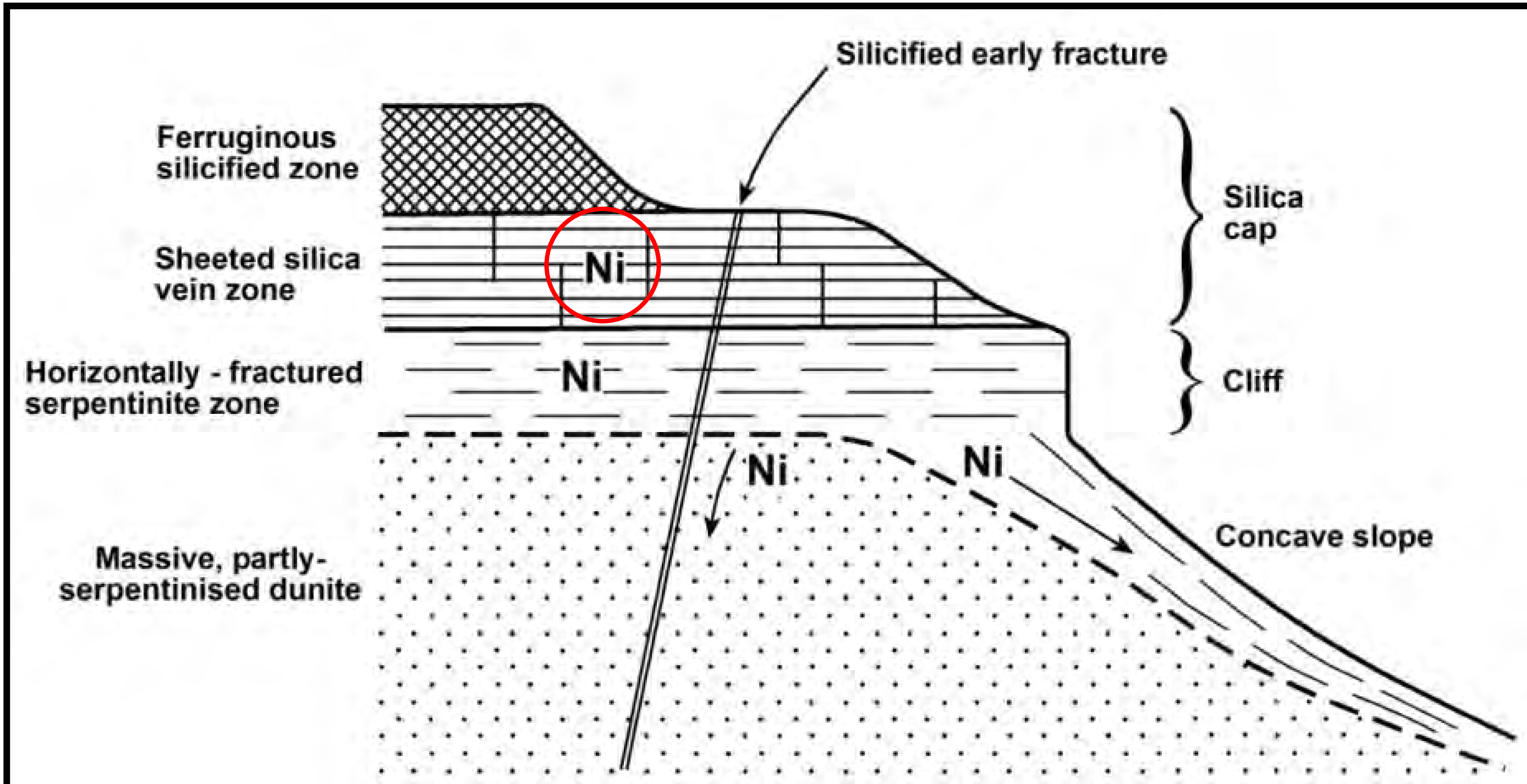


Vertical geochemical variations in two drill-holes, Shear Zone hill: Ni

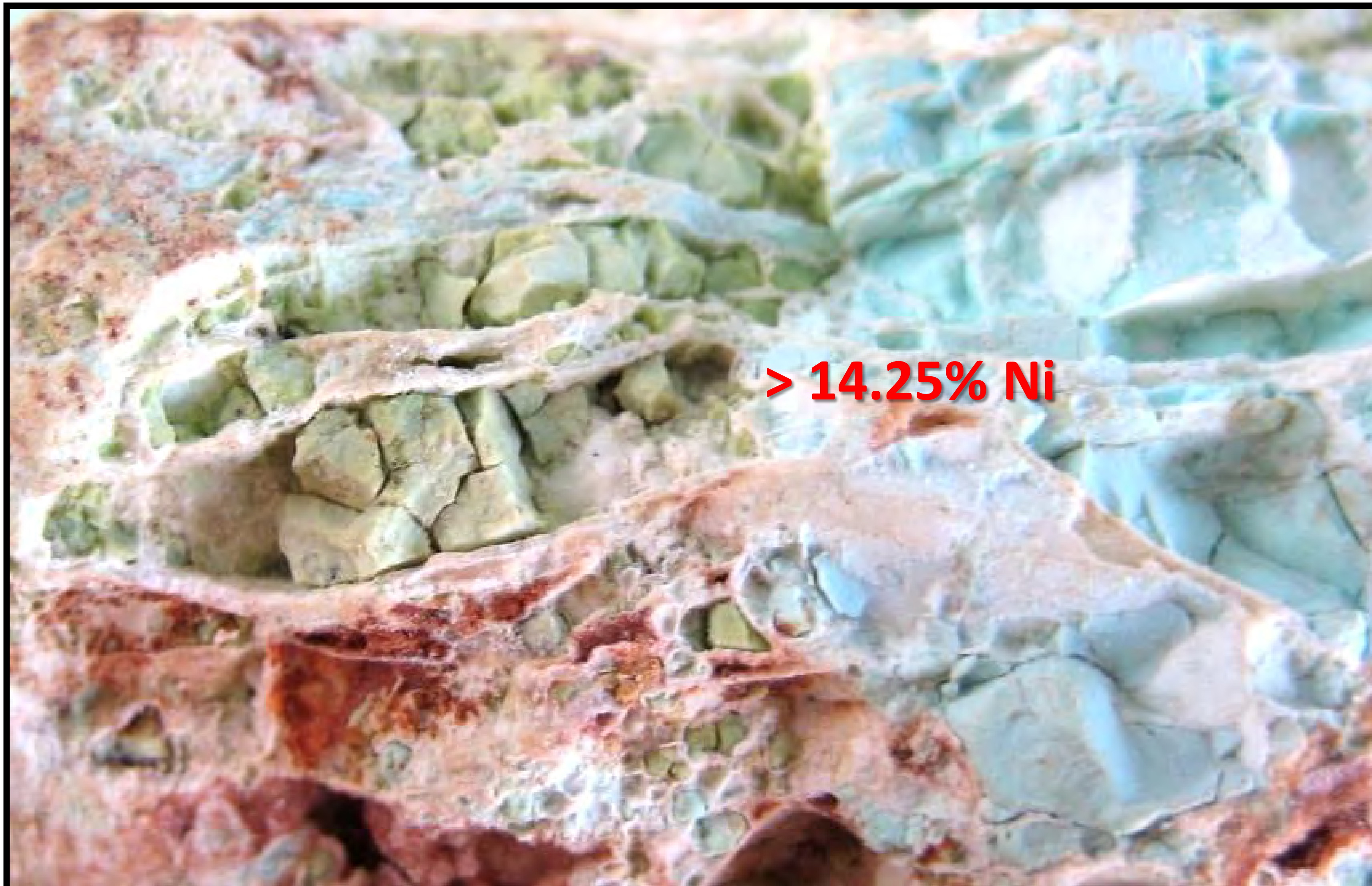


Nickel enrichments in sheeted silica vein zone

Serpentinite host: up to 1.84 % Ni

Serpentinite with fine silica veinlets: up to 4 % Ni

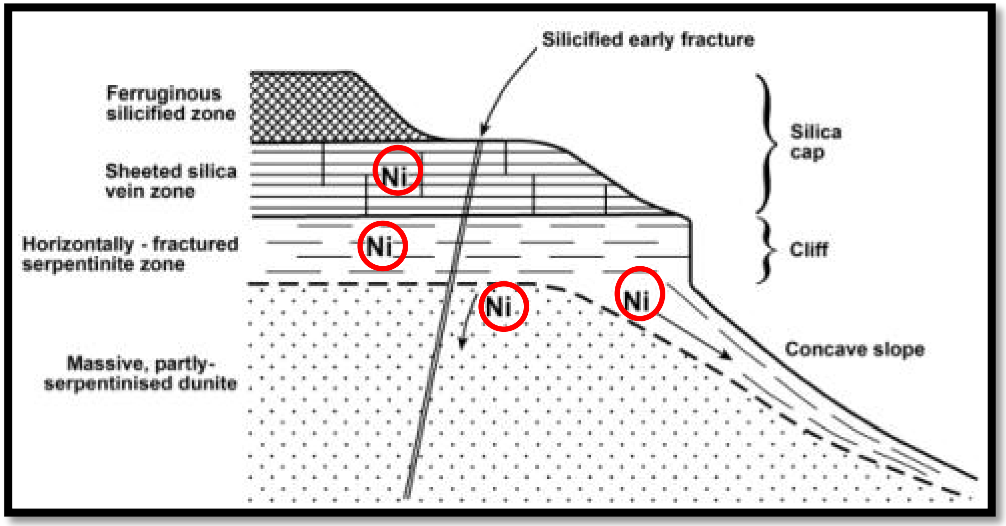
Silica veins: up to 5.18 % Ni



Pale green (or locally green-blue) Ni-rich mineral in drusy vug, large silica vein

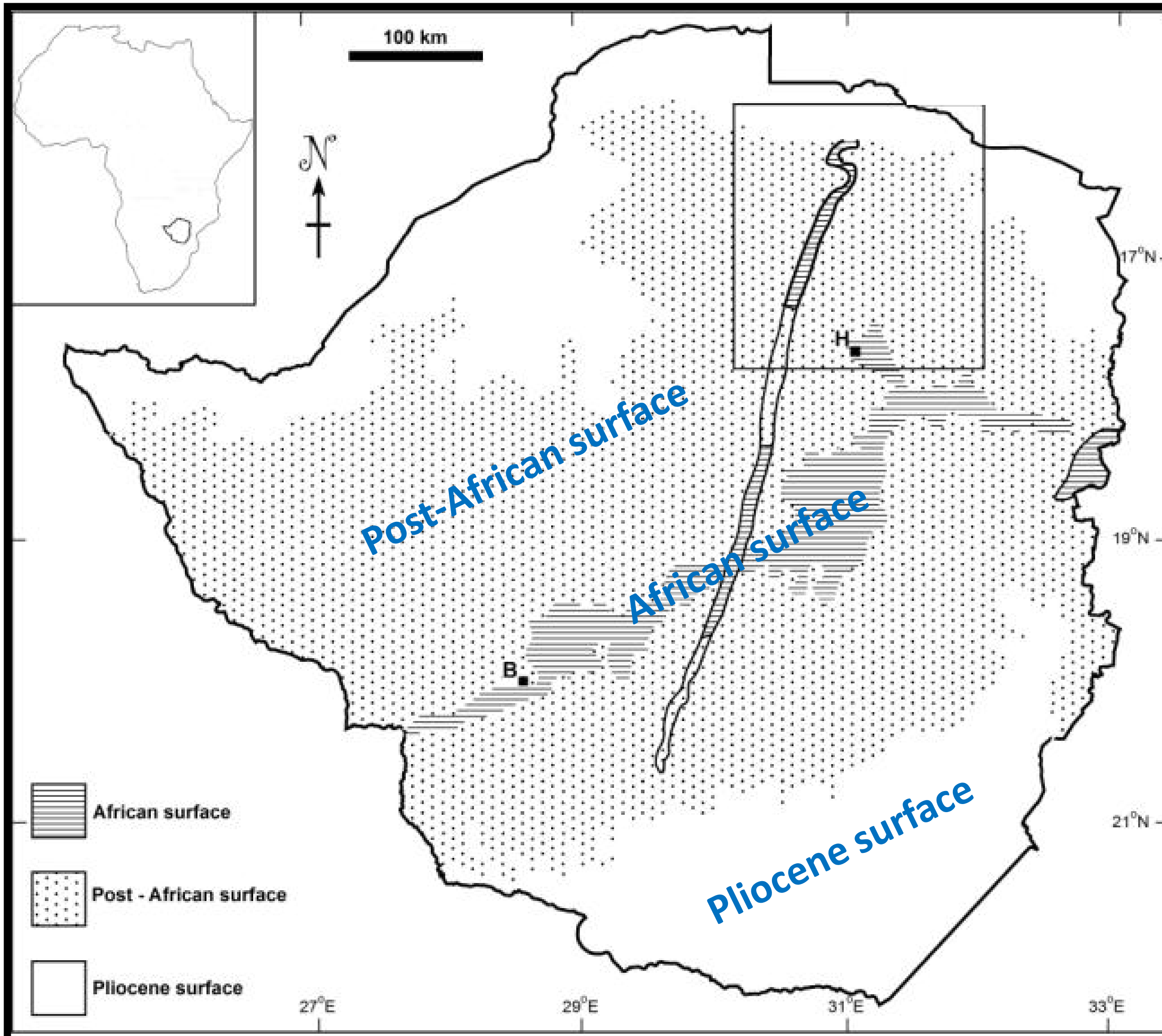
Mineralogy of nickel enrichments

- Discrete fracture-related minerals in serpentinite
  - ‘**Garnierite**’ (?), a hydrated Ni-Mg silicate
- Silica veins (in sheeted silica vein zone)
  - Fine-grained, amorphous, **Ni-rich serpentine** (?)
- Pervasive enrichments in serpentinite
  - **Ni-rich chrysotile** and/or **goethite** (?)



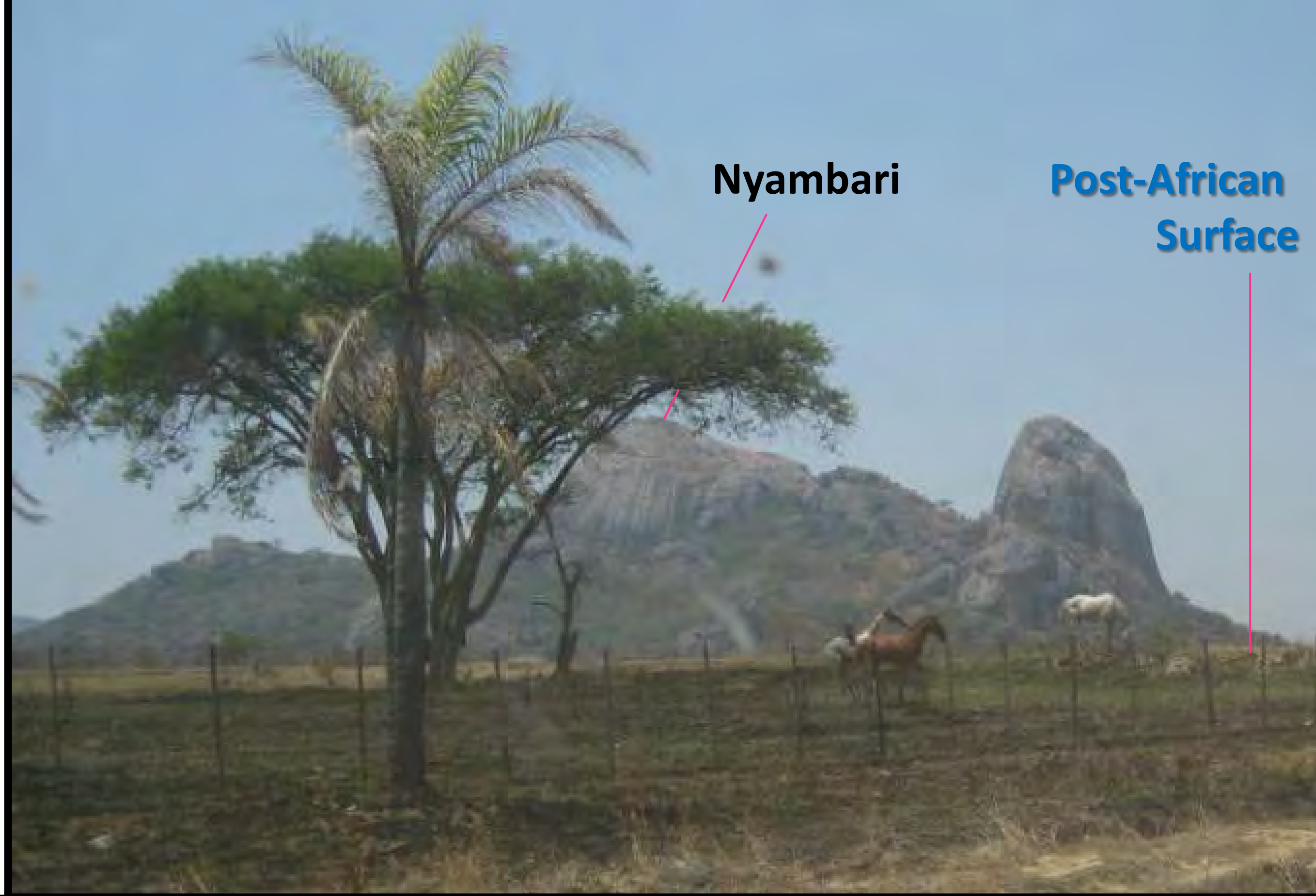
All formed by ion exchange and redeposition from nickel-bearing solutions

8. Landscape evolution in northern Zimbabwe

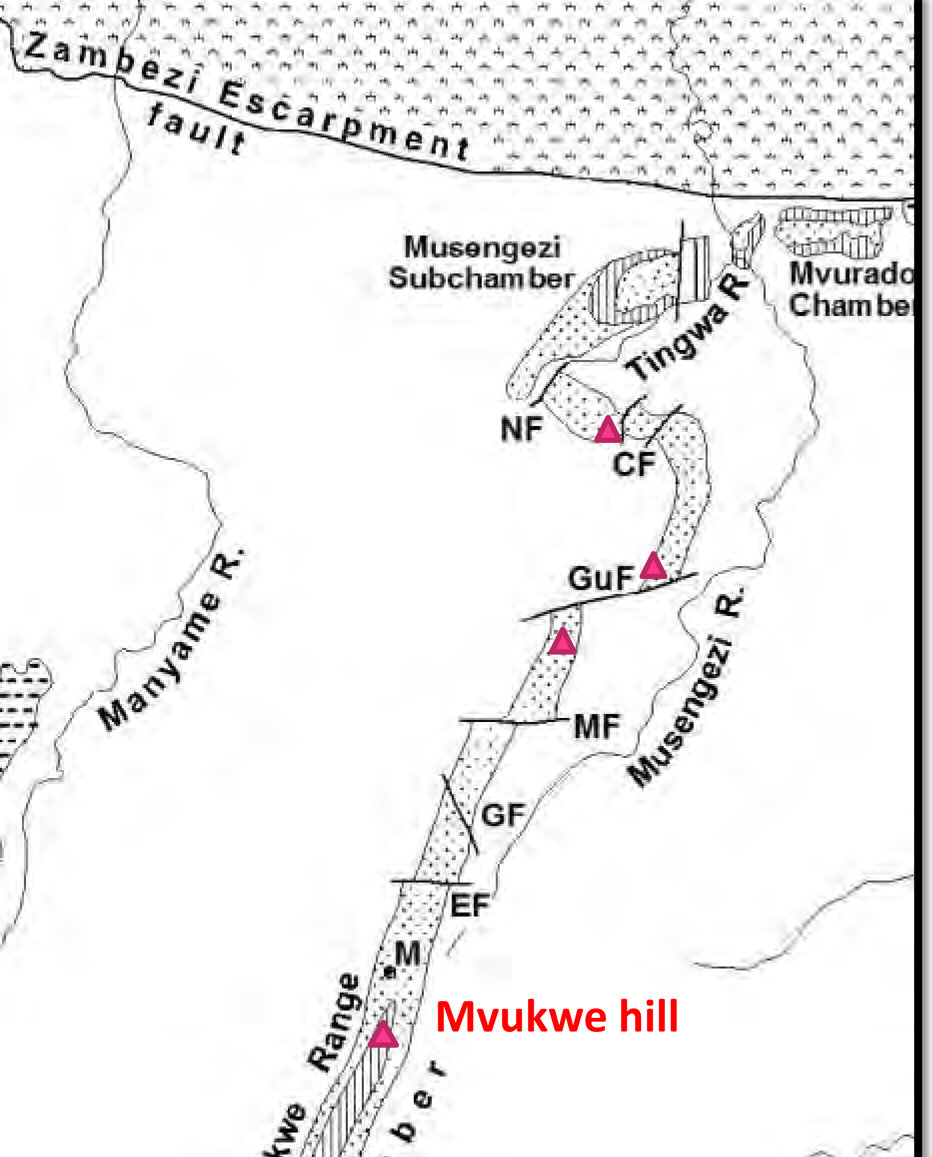


Erosion surfaces of Zimbabwe

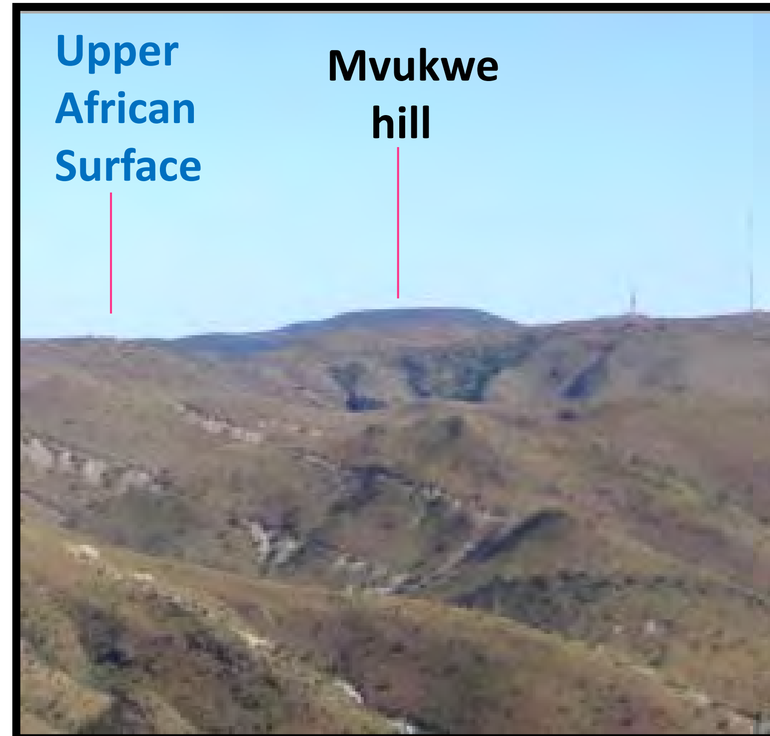
9. The African Surface on the North Dyke



Relationship between the lower surface in the Mvurwi section and the African Surface



Summits of the North Dyke



Relationship between the Upper African Surface and a pre-African Surface (Mvukwe hill)

10. Uplift and rejuvenation in northern Zimbabwe

- Accelerated erosion, Zambezi and Limpopo valleys, 133-118 Ma, Early Cretaceous (apatite fission track ages: Belton, 2006)

➡ Gondwana break-up,
initiation of African Surface in Zimbabwe

- Accelerated erosion, Zambezi and Limpopo valleys, 48-37 Ma, end-Paleogene (apatite fission track ages: Belton, 2006), *and*
- Accelerated sedimentation, Zambezi and Limpopo deltas 34-24 Ma (Walford et al., 2005; Burke and Gunnell, 2008)

➡ Epeirogenic uplift of central watershed,
initiation of Post-African Surface in Zimbabwe (Moore et al., 2009)

- Uplift, southern rift shoulder, Cabora Bassa rift basin (Zambezi valley), along Zambezi Escarpment fault, Triassic onwards (Broderick, 1990)

➡ Sedimentary surge (?), Zambezi delta, Late Cretaceous (75-65 Ma) (Walford et al., 2005),
incision of deep river gorges through Escarpment,
deposition of alluvial fan deposits at Escarpment foot,
erosional loss of uppermost Karoo sequence,
terracing of major rivers across Zambezi valley floor,

➡ northward erosional loss of upper African Surface, North Dyke, *and*
northward increase in preserved olivine at surface, North Dyke, *and*
lower African Surface, Mvurwi section, North Dyke

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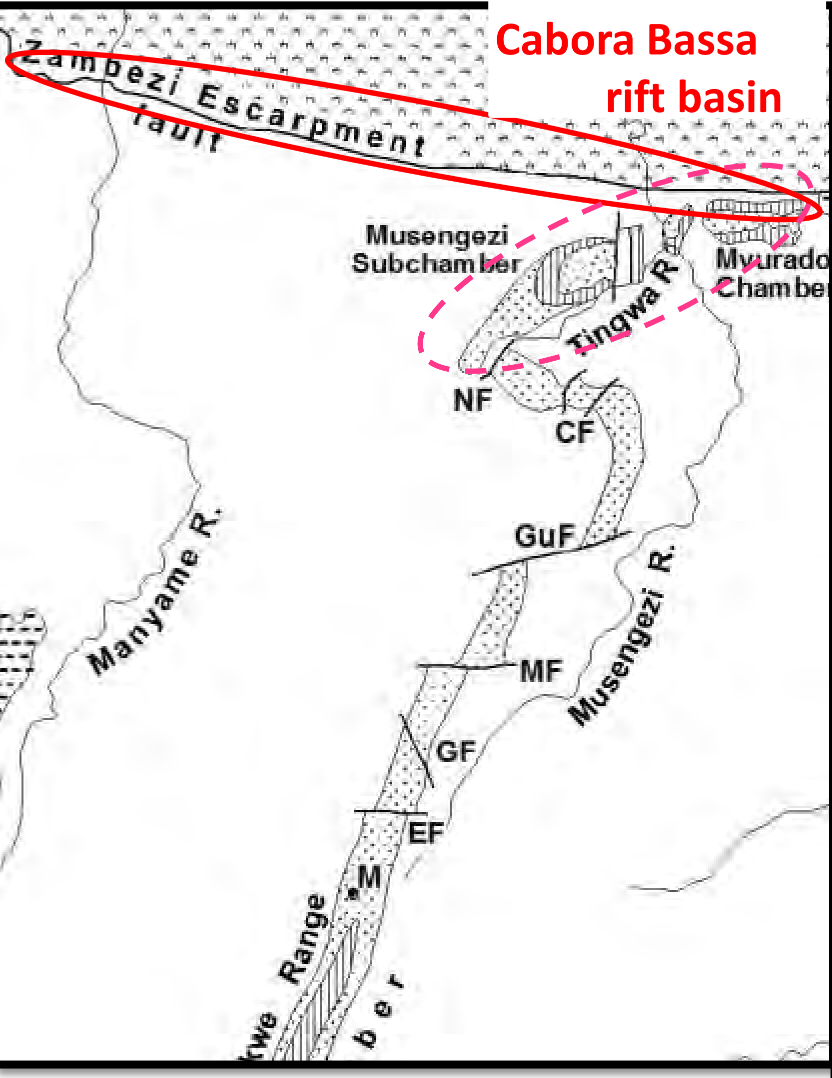
→ northward erosional loss of Upper African Surface, North Dyke, *and*
northward increase in preserved olivine at surface, North Dyke, *and*
formation of Lower African Surface, Mvurwi section, North Dyke



Snake's Head section
and the Zambezi Escarpment fault

10. Uplift and rejuvenation in northern Zimbabwe

- Accelerated erosion, Zambezi and Limpopo valleys,
133-118 Ma, Early Cretaceous (apatite fission track ages: Belton, 2006)

→ Gondwana break-up,
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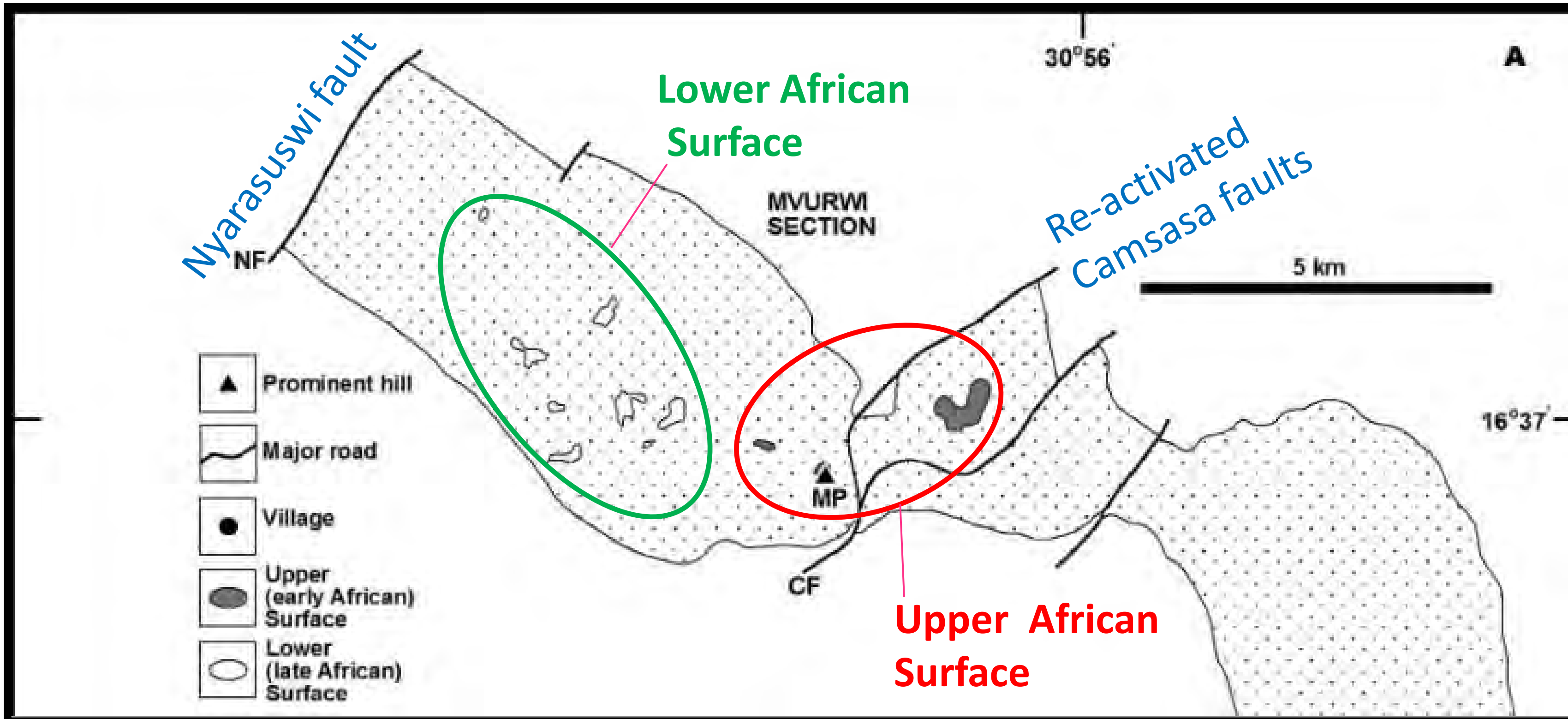
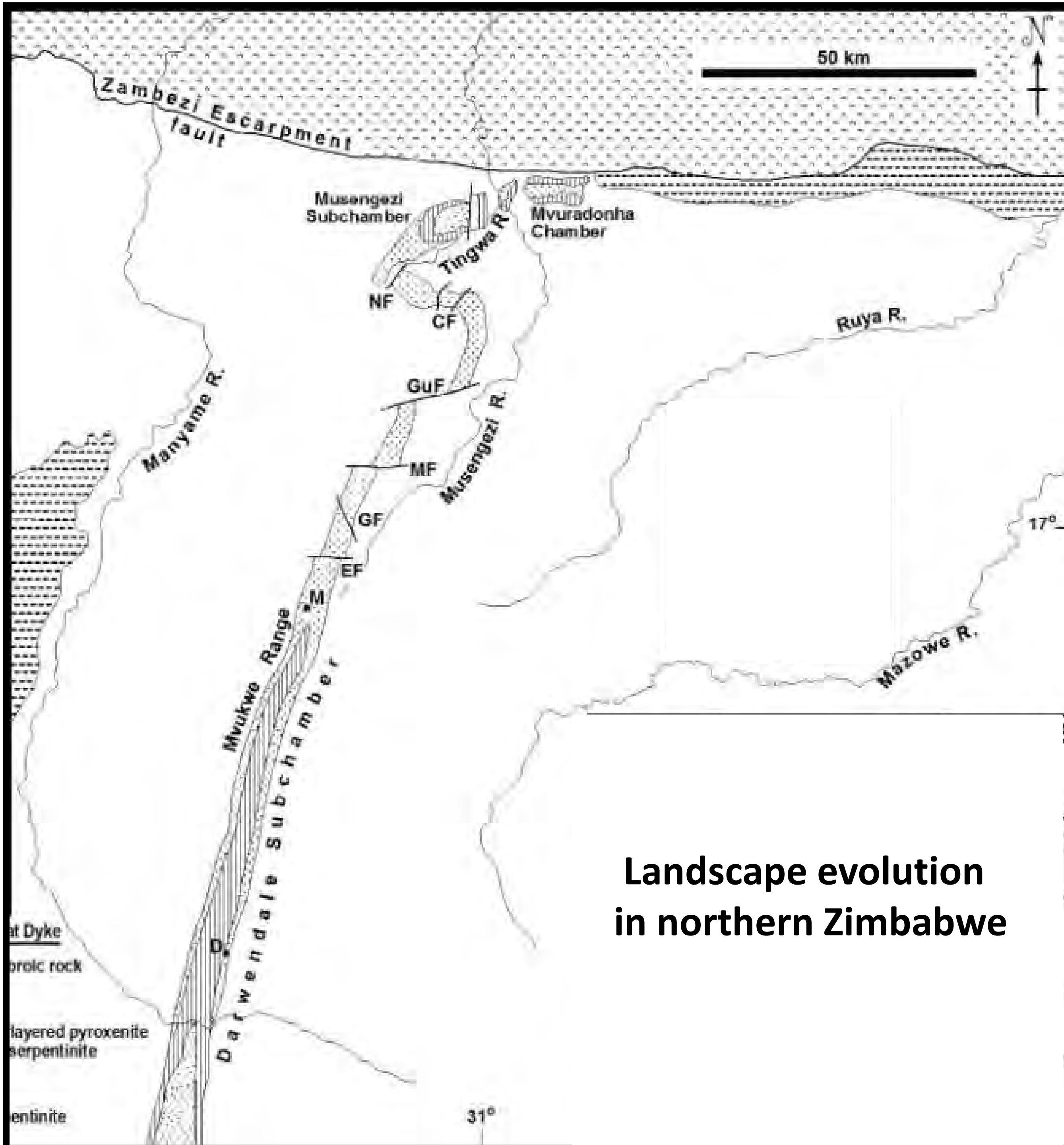
northward increase in preserved olivine at surface, North Dyke, *and*
lower African Surface, Mvurwi section, North Dyke



Isolated Upper African Surface relics in the eastern Mvurwi section - A result of post-uplift re-activation of Proterozoic, Zambezi belt faults?



Landscape evolution in northern Zimbabwe

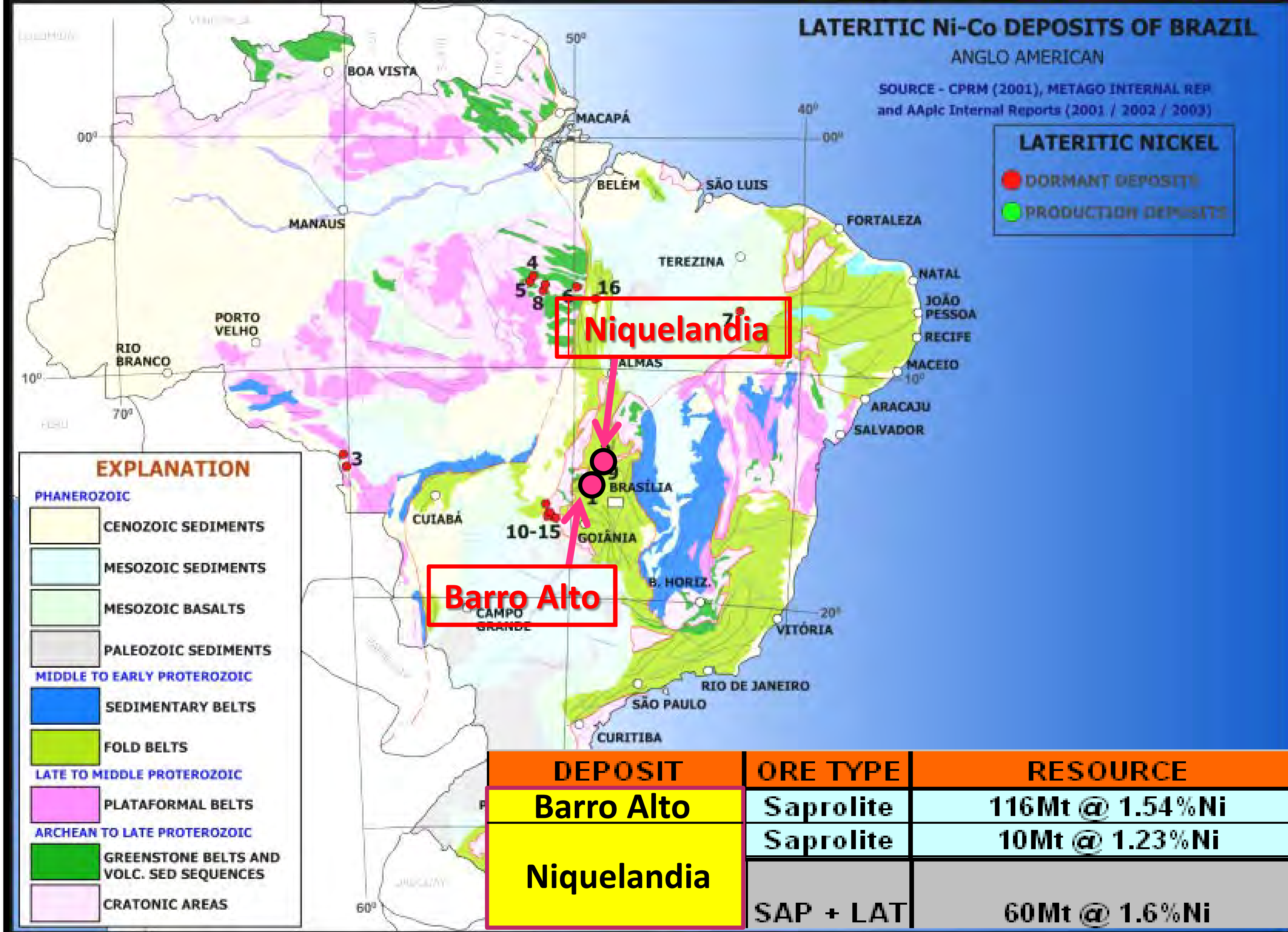
11. Nickel laterite deposits on the Great Dyke

Deep, Ni-enriched regoliths with silica caps in North Dyke indicate prolonged weathering under 'greenhouse' conditions (i.e., tropical weathering)

Tropical weathering =
- cold month mean temperatures 15-27°C
- warm month mean temperatures 22-31°C
- precipitation > 1000 mm/year.

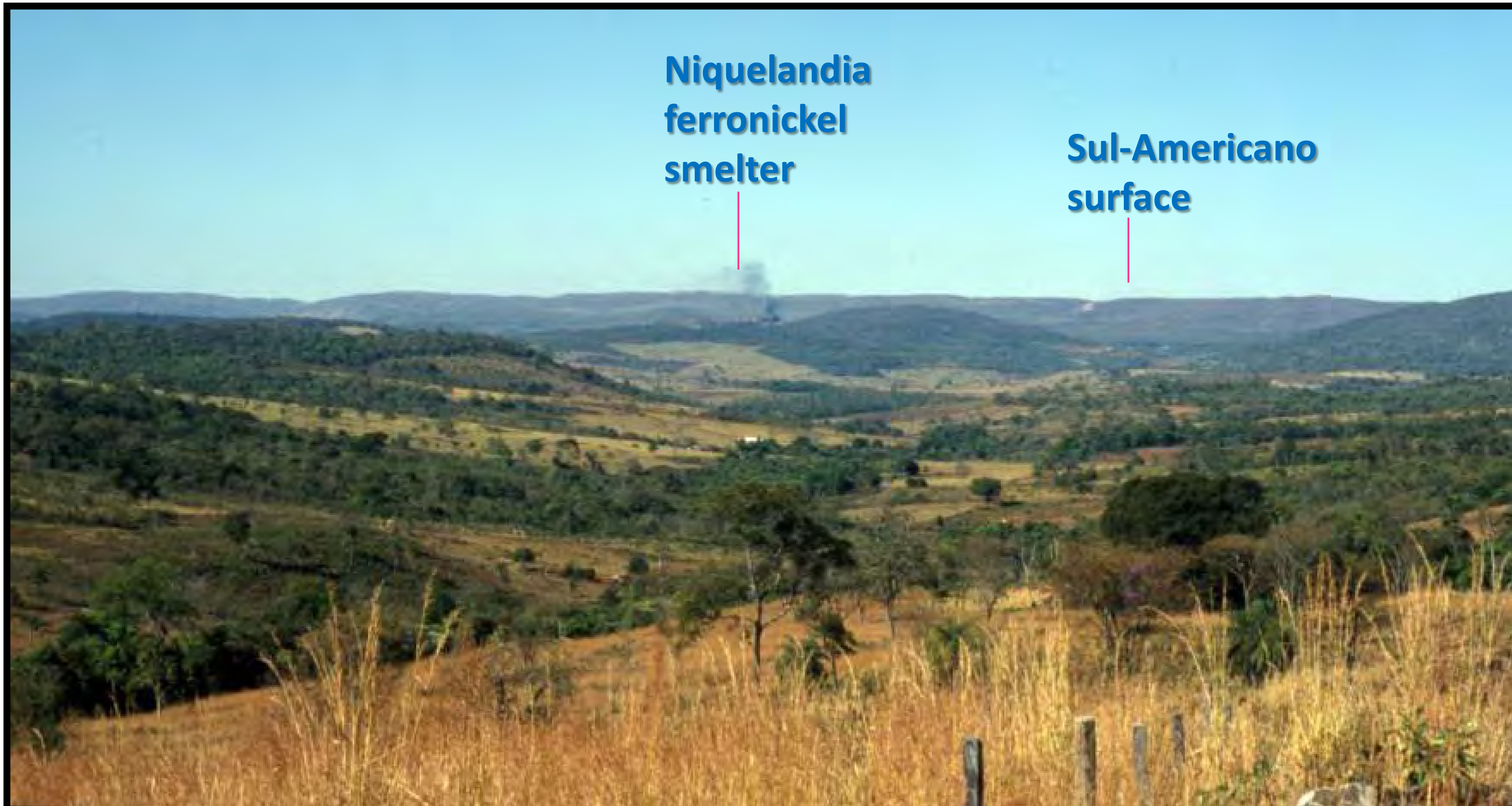
Repeated, widespread lateritisation events, e.g., at 100, 65 and 48 Ma

Most important factors in nickel laterite development →
- bed-rock
- climate
- tectonics
- geomorphology
- drainage

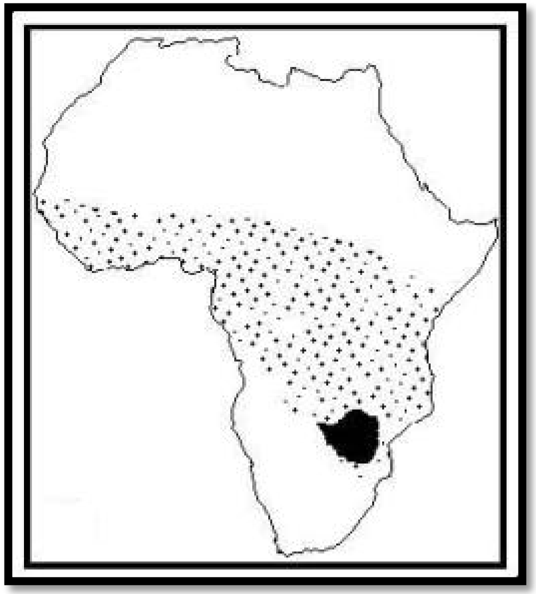


DEPOSIT	ORE TYPE	RESOURCE
Barro Alto	Saprolite	116Mt @ 1.54%Ni
Niquelandia	Saprolite	10Mt @ 1.23%Ni
	SAP + LAT	60Mt @ 1.6%Ni

Nickel laterite deposits in central Brazil: Niquelandia and Barro Alto

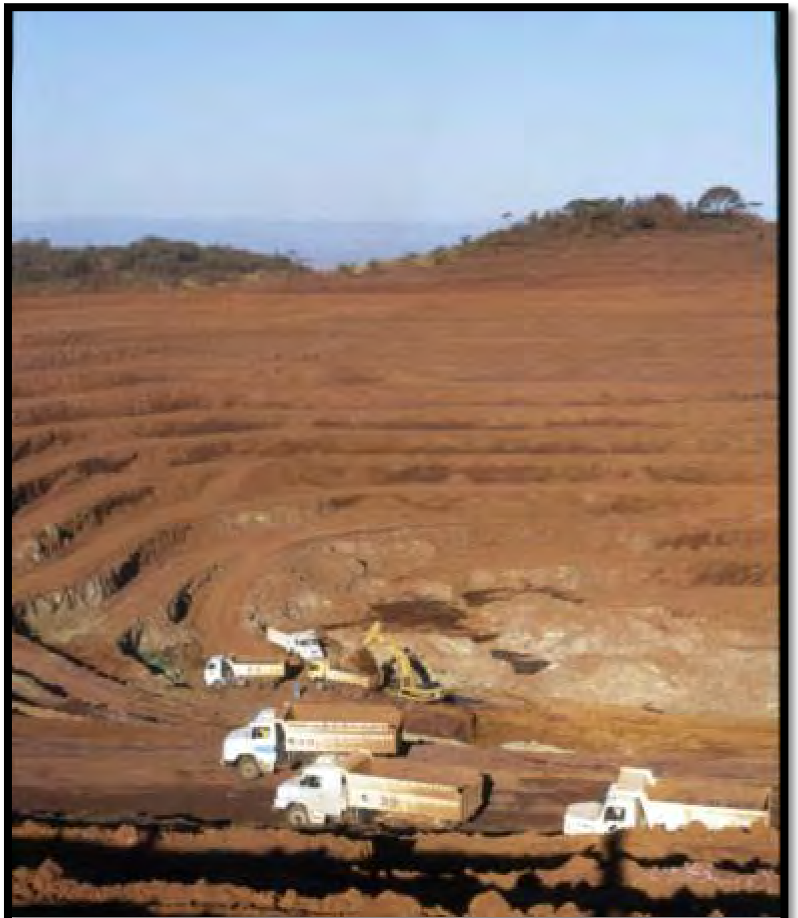


The Sul-Americano erosion surface (with silica cap), Niquelandia, central Brazil

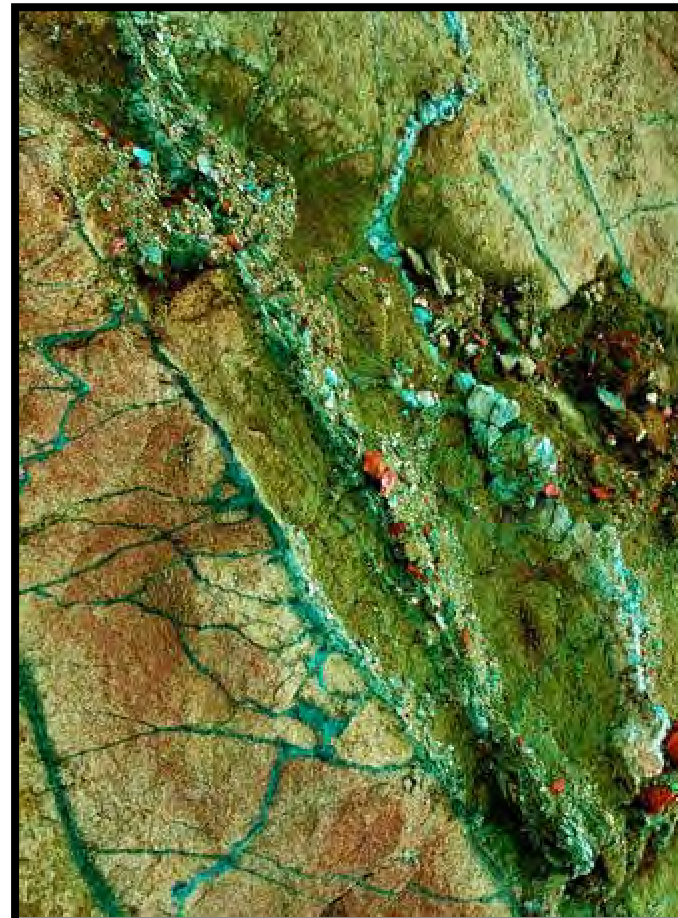


Africa's tropical weathering zone

Location of North Dyke nickel laterite deposits on more elevated, sub-tropical eastern side of southern Africa



Mining at Niquelandia



Rich Niquelandia ore with green garnierite veins

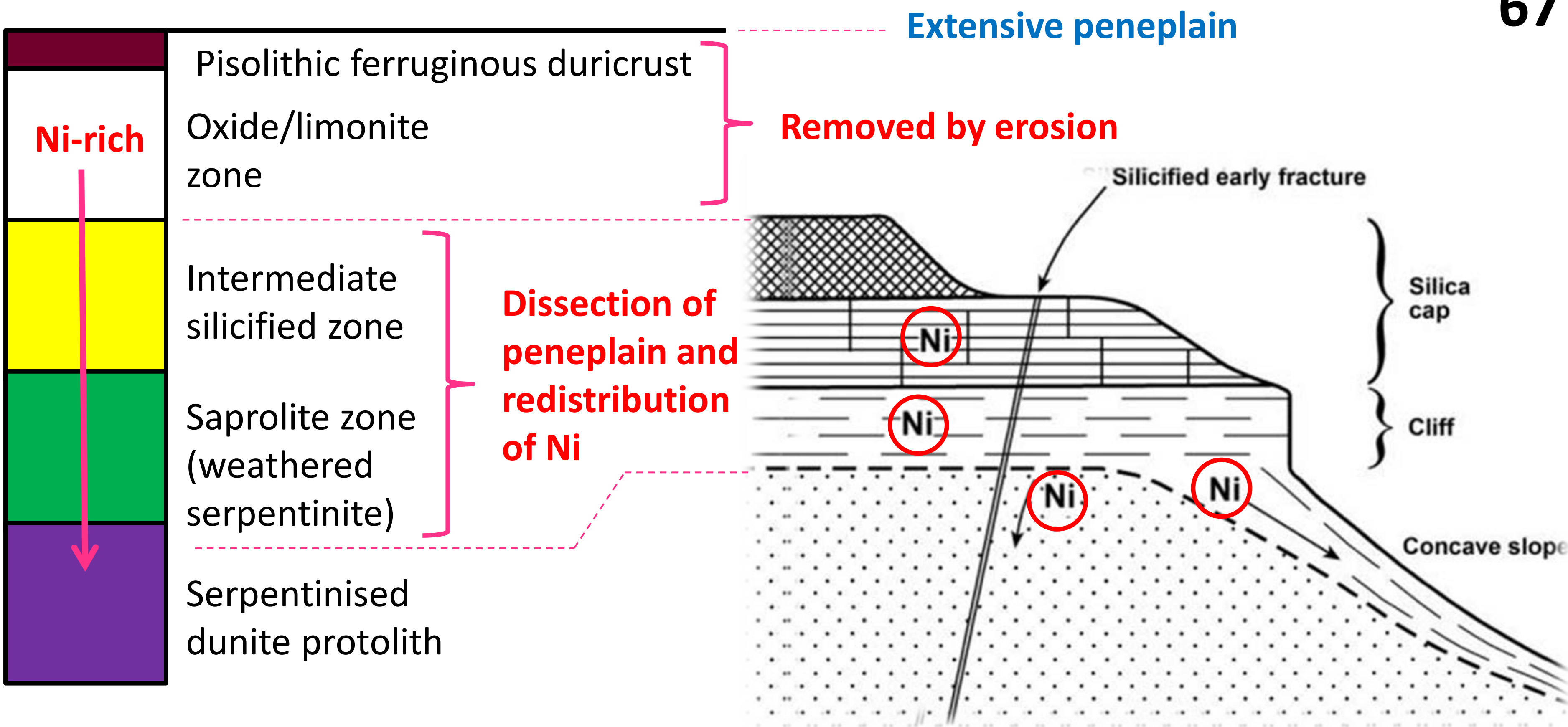
Nickel laterite deposits on the Great Dyke

Deep, Ni-enriched regoliths with silica caps in northern part of Great Dyke indicate prolonged weathering under 'greenhouse' conditions (i.e., tropical weathering)

Tropical weathering = {
cold month mean temperatures 15-27°C
warm month mean temperatures 22-31°C
precipitation > 1000 mm/year.

Repeated, widespread lateritisation events, e.g., at 100, 65 and 48 Ma

Most important factors in nickel laterite development → bed-rock
climate
tectonics
geomorphology
drainage



1. Initial peneplanation

2. After uplift, erosion and lowering of water-table

Simplified evolution of landscape, regolith and nickel laterite on North Dyke

Dr Peter Cotterill (died 1983)

Identified the Great Dyke nickel laterites, ca. 1970

Thankyou