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# Geodynamic setting of komatiite-hosted Ni sulphide deposits of the Agnew-Wiluna Belt

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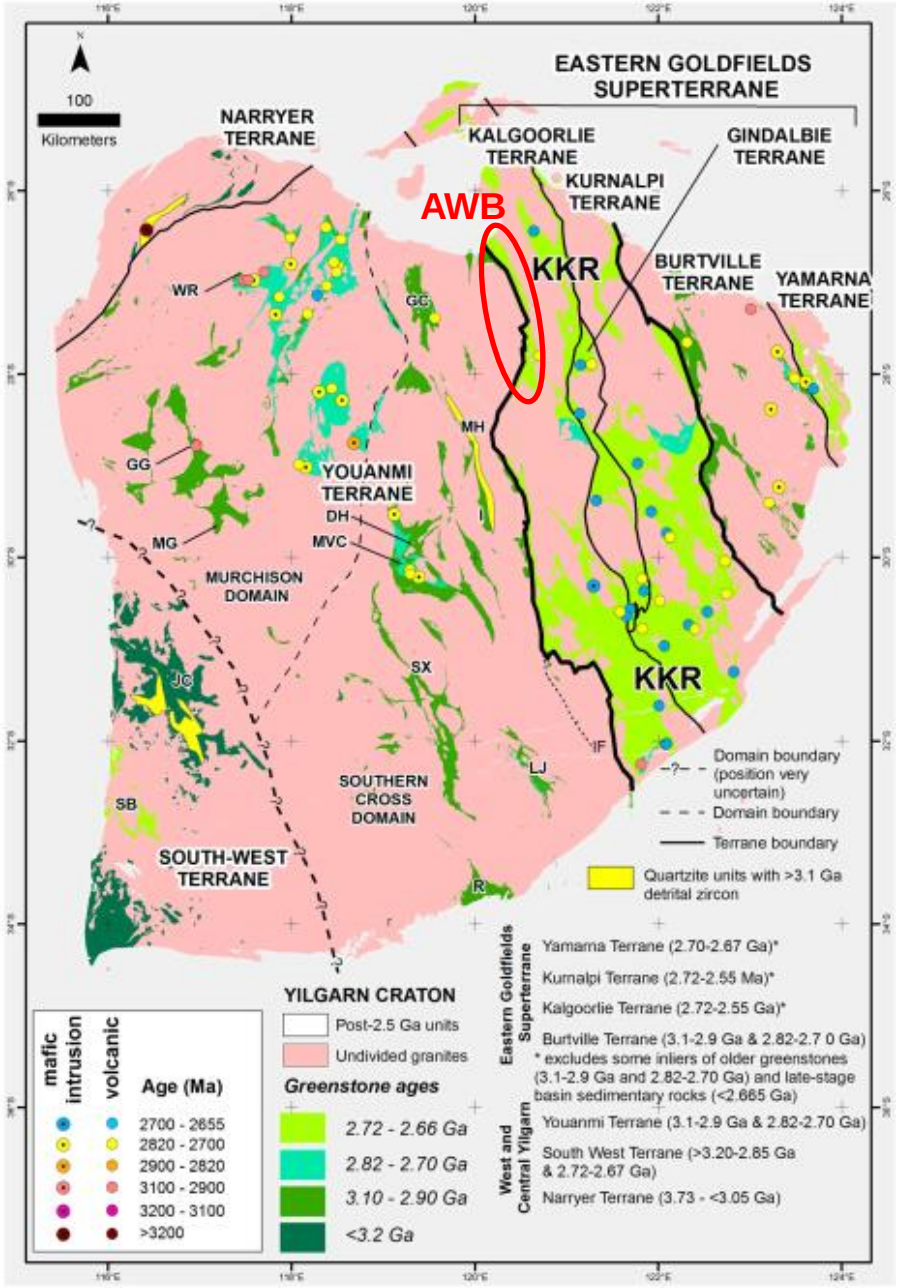
# Introduction – Yilgarn craton

## Long history of assembly

- 4 Ga proto-cratonic nucleus.
- 3 major periods of rifting, reworking and crustal growth.

## Associated komatiite-hosted Ni mineralisation

- 3.10-2.90 Ga:
  - Ravensthorpe, Forrestania, Lk Johnston.
- 2.82-2.70 Ga:
  - Duketon, Windarra.
- 2.72-2.66 Ga:
  - Kalgoorlie-Kurnalpi Rift
  - Honeymoon Well, Mt Keith, Yakabindie, Cosmos, Perseverance, Black Swan, Kambalda, Widgiemooltha.
  - Majority of Australia's Ni production.

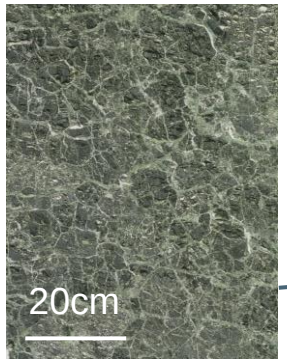


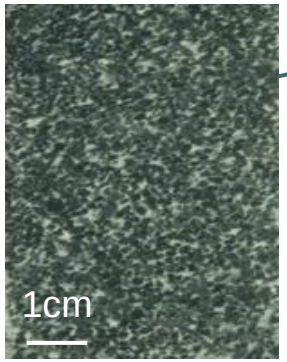

(from Witt et al., 2020)

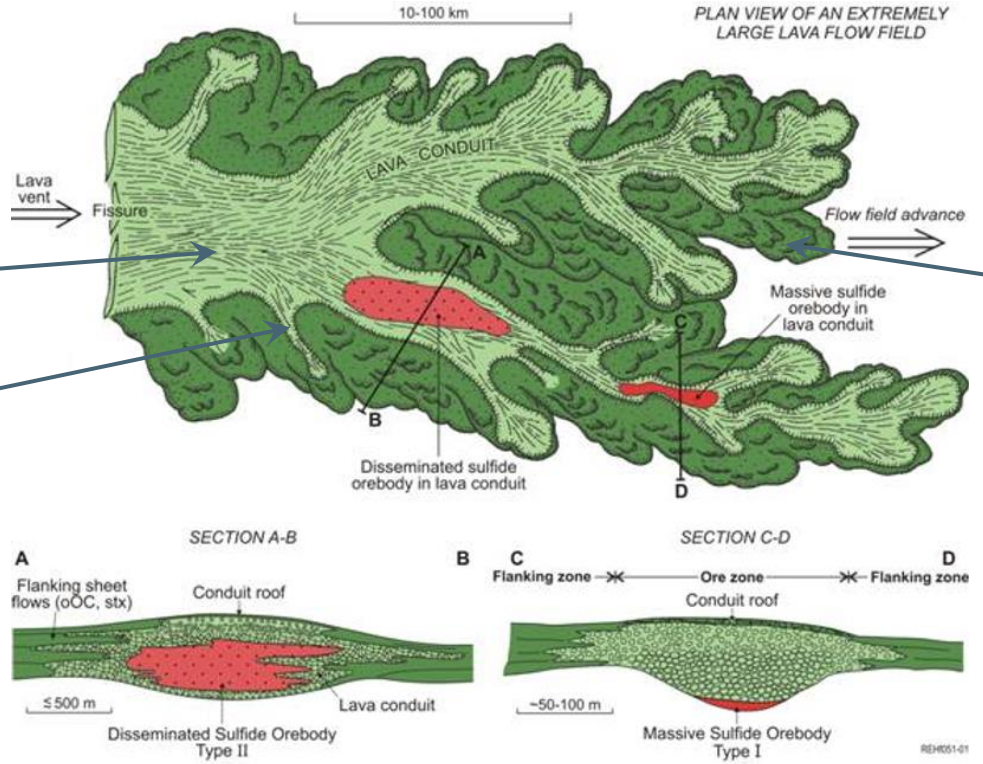
# Architecture of komatiitic flow fields

## Reconstucting the volcanic edifice

- Emplaced by inflationary flow processes (cf. flood basalts).
- Nickel sulphides are hosted by lava pathways of a variety of scales.
- Komatiite textures (adcumulate, orthocumulate, spinifex-textured) are used to infer sample position within the volcanic edifice.
- Most komatiites can be treated as mixtures of olivine + komatiite liquid: volatile-free $Al_2O_3$ content is a proxy for trapped liquid component.



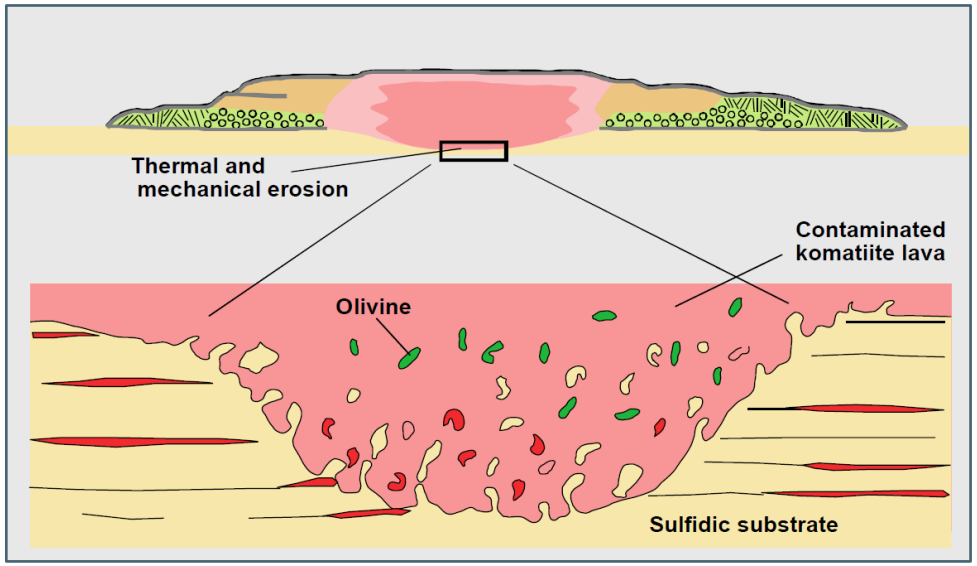


(Hill et al., 1995)

# The exploration challenge

**Tube-fed flow of komatiite lava causes thermo-mechanical erosion of the substrate and assimilation of S from the substrate**

- Critical to map lava pathways and reconstruct the volcanic architecture.
- BUT not all pathways will host Ni sulphide.




Kambalda: ore formation in komatiitic lava pathways (adapted from Hill et al., 1995)

**The AWB - a mature exploration space**

- Majority of Ni deposits discovered in late 1960's to early 1970's.
- Top 200-300m intensively drilled
  - Essentially exploring under cover.
- Typical orebody dimensions ~1000x200x<50m
  - Tiny target.

**3D modelling as an exploration tool**

- Powerful desktop 3D modelling packages.
- Under utilised geological, geochemical & geophysical database.
- Allows us to reconstruct volcanic architecture.



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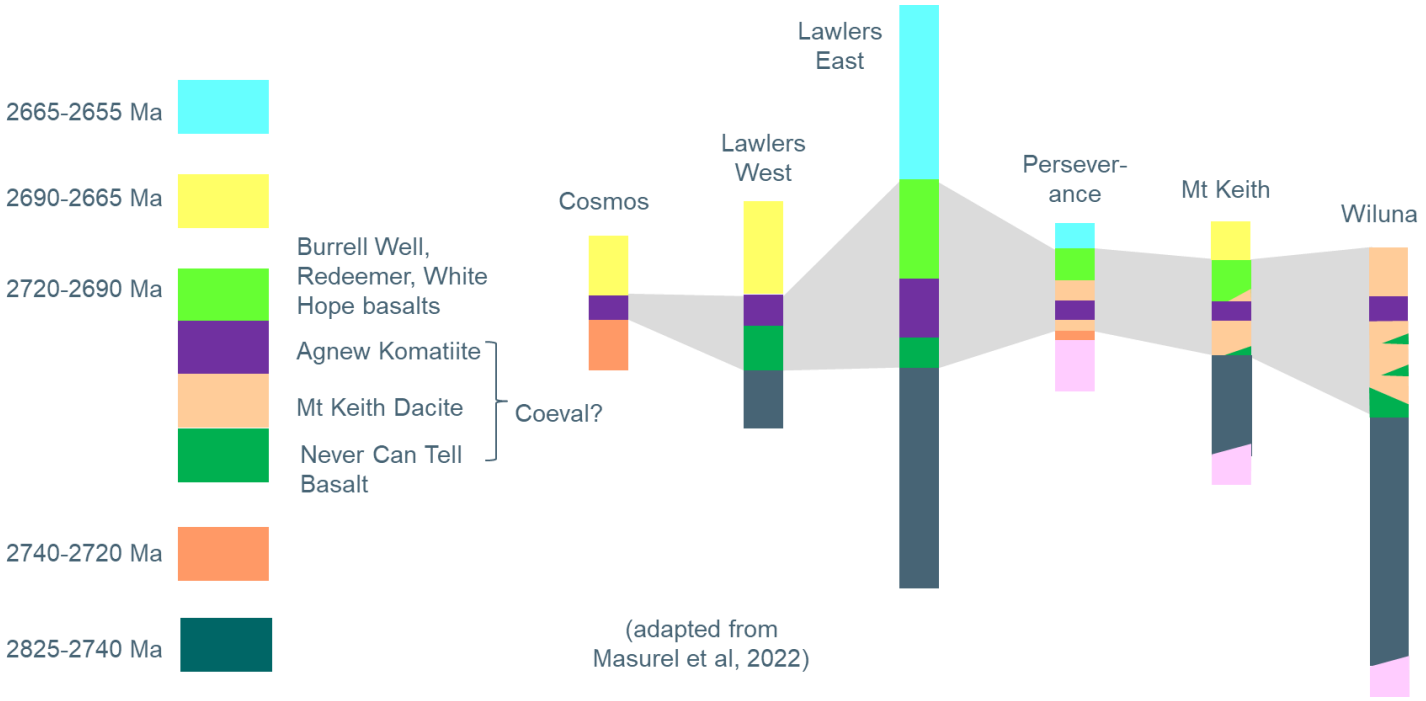
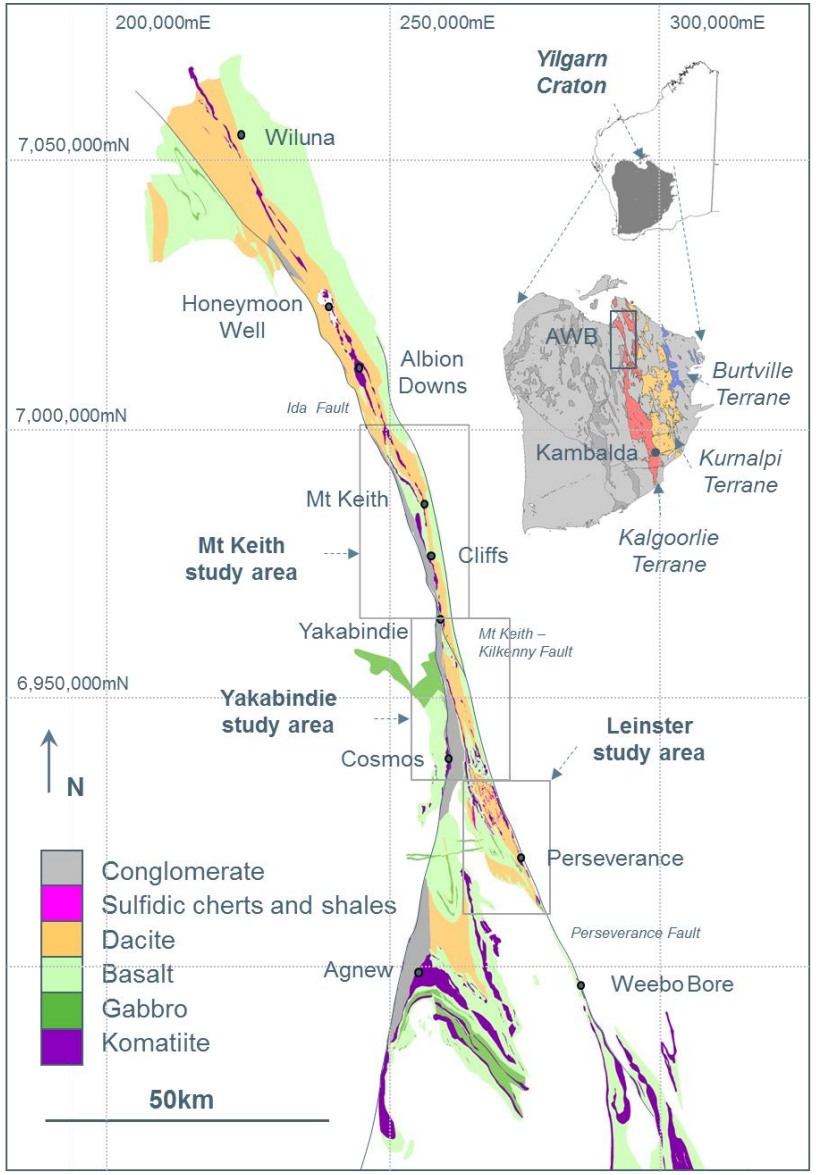
# Agnew-Wiluna Belt regional geology

## Key features

- Dominated by rocks of the 2720-2690 Ma rifting event (in grey below).
- Host to 3 of the largest komatiite-hosted Ni sulphide deposits in the world:
  - Perseverance: >1 Mt Ni, Type 1 (massive/matrix)
  - Six Mile Well: >2 Mt Ni, Type 2 (disseminated)
  - Mt Keith: >3 Mt Ni, Type 2 (disseminated)



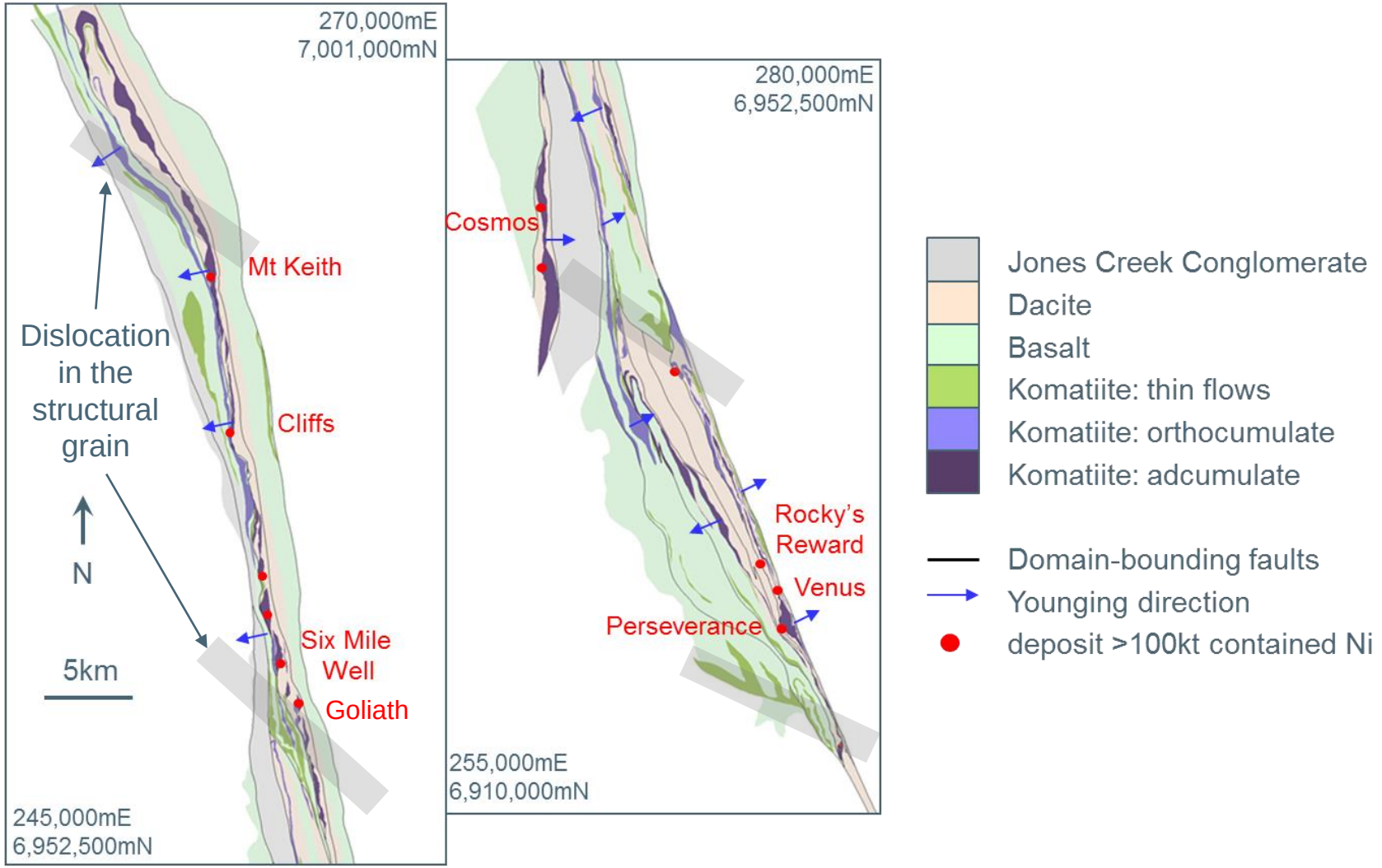
# Regional komatiite distribution

## Structure

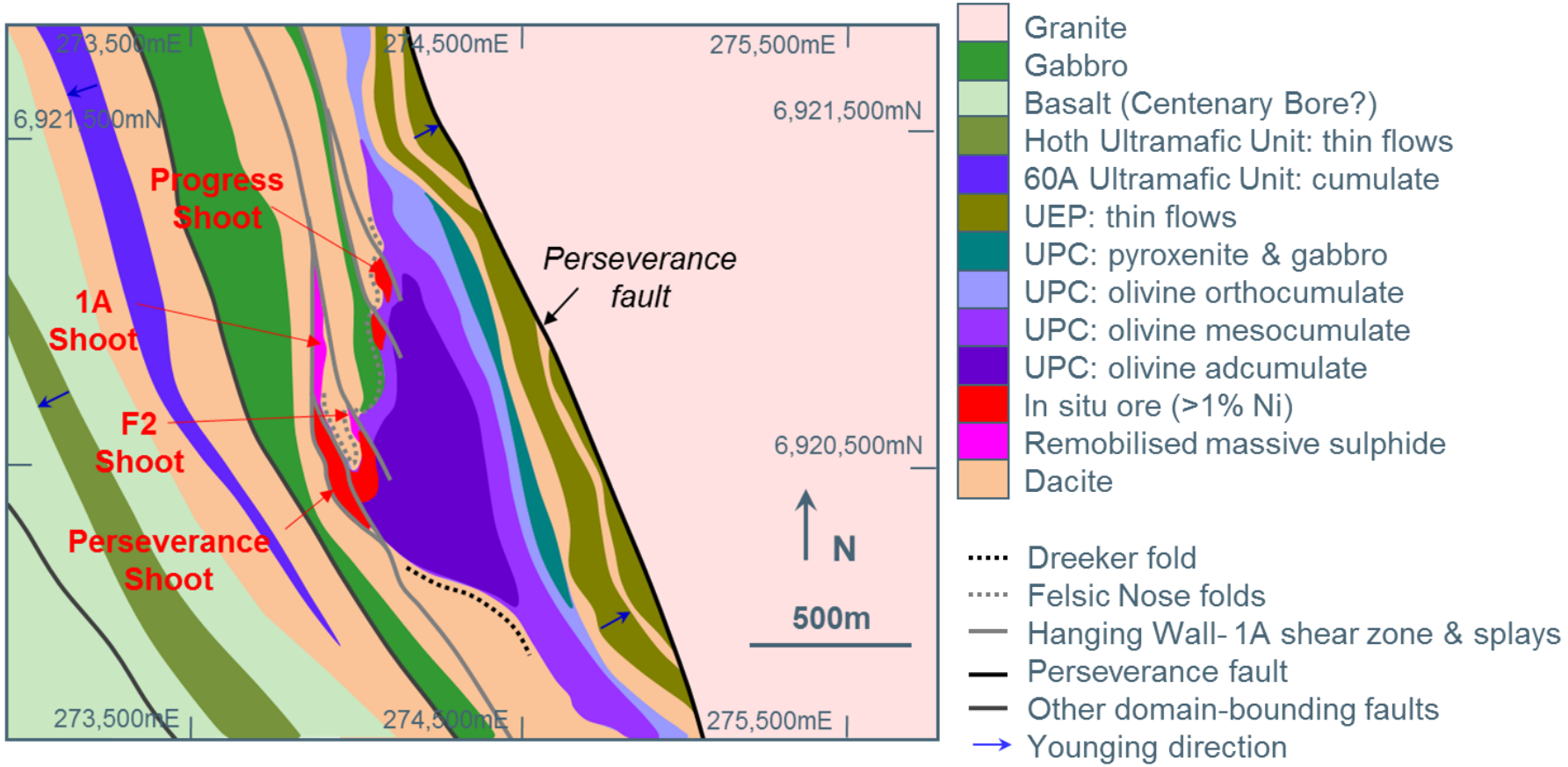
- Stratigraphy now subvertical:
  - Map view is ~ long section.
- NNW-trending structural grain:
  - Dislocated by NW-trending zones.

## Volcanic architecture

- Proximity to rift axis:
  - Proximal: dacites and cumulate-rich komatiites.
  - Distal: basalts and thin-flow komatiite units.
- Pathway positions:
  - Marked by lenticular cumulate bodies,
  - Shallow plunge,
  - Primary volcanic grain was N- to NNE-trending.



# Perseverance: a giant lava pathway




Plan view at 400mRL

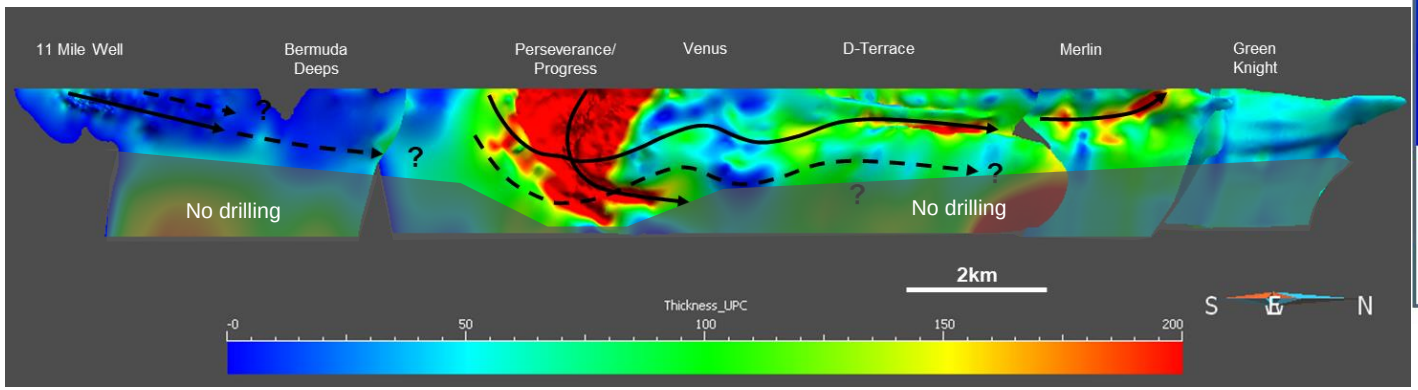
# Perseverance deposit: funnelling of lava flow?

## Perseverance lava pathway

- Thickness of ultramafic unit highlights position.
- Plunge is curvilinear and flattens out at depth.
- Olivine-cumulate lens thins dramatically with depth.
- Possibly vent-proximal?

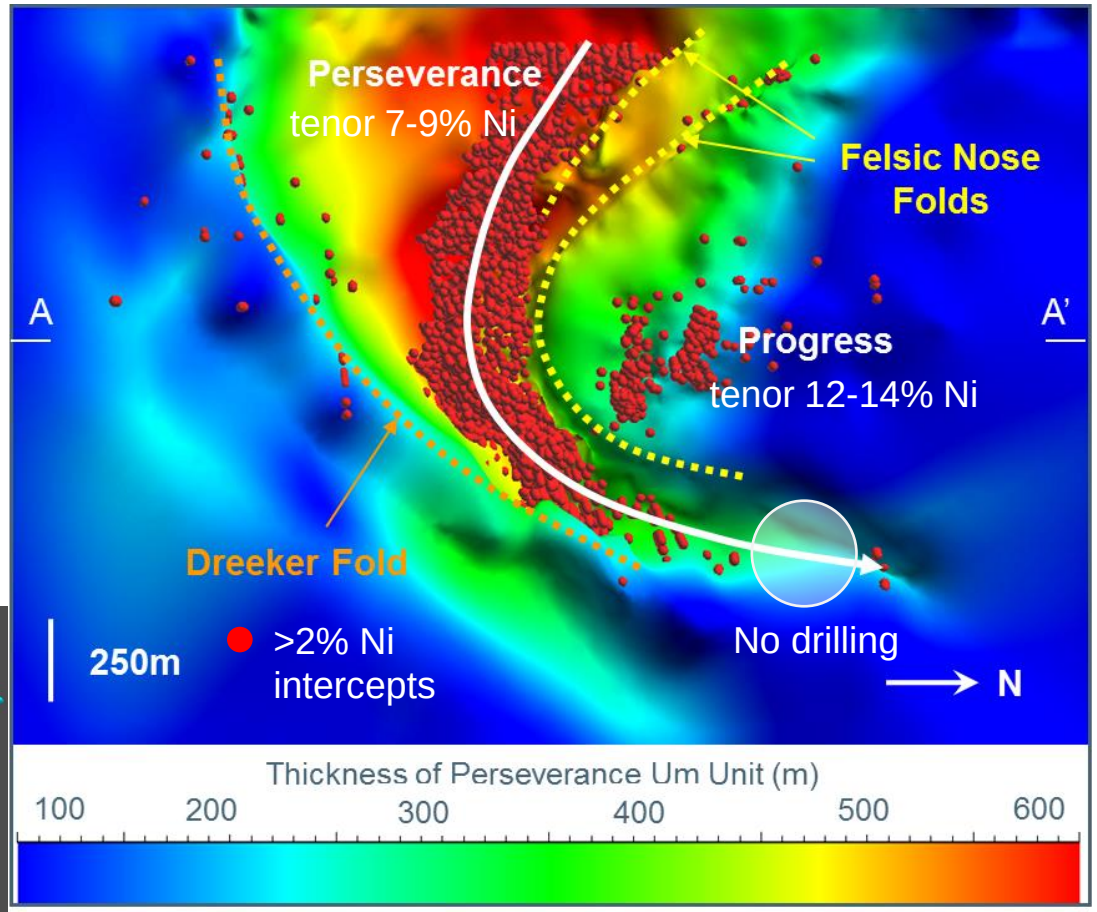
## Volcanic architecture

- Multiple lava pathway positions within the Perseverance ultramafic unit (cf. Kambalda)?




Long section looking W

Long section looking W



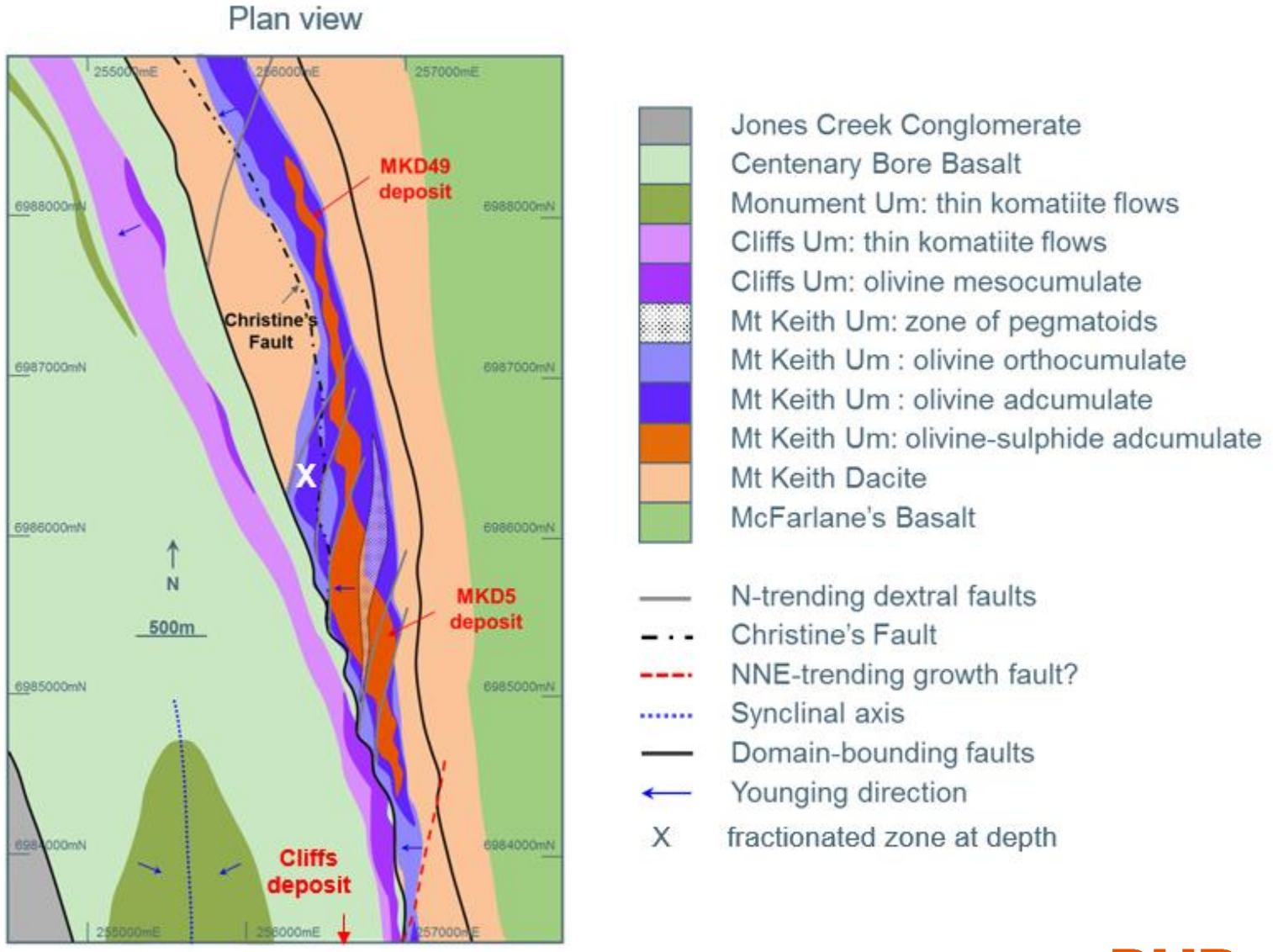
# Mt Keith: juxtaposition of lithofacies

**Mt Keith ultramafic unit**

- Adcumulate pathway positions linked by orthocumulate sheets.
- Intercalated with dacite,
  - Rift axis.

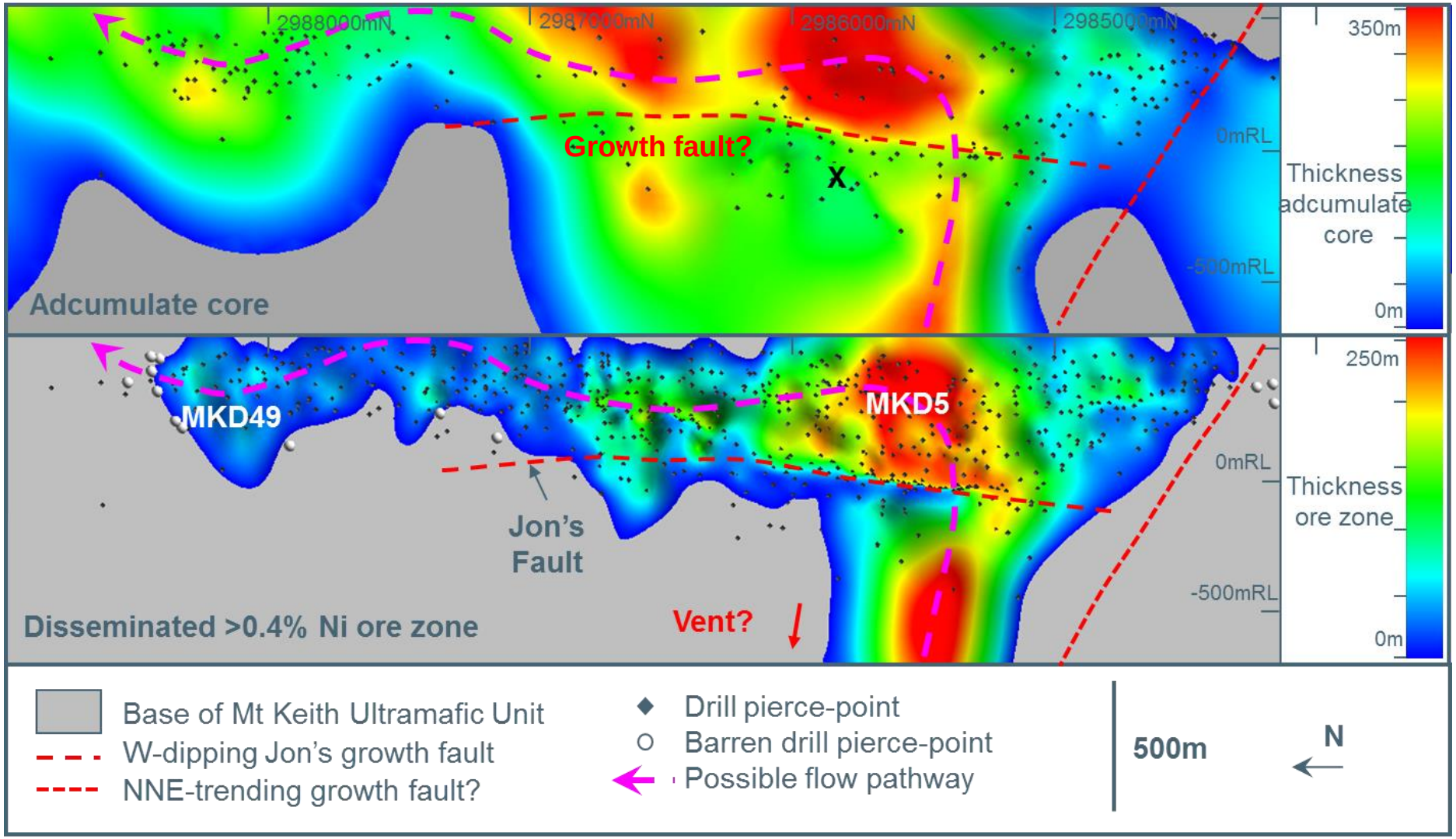
**Cliffs ultramafic unit**

- Mesocumulate pathway positions linked thin komatiite flows.
- Intercalated with basalt,
  - Rift margin.



# Mt Keith deposit: bend in lava pathway is key

Long section looking E




X = thickest development of basal orthocumulate zone and of upper fractionated zone

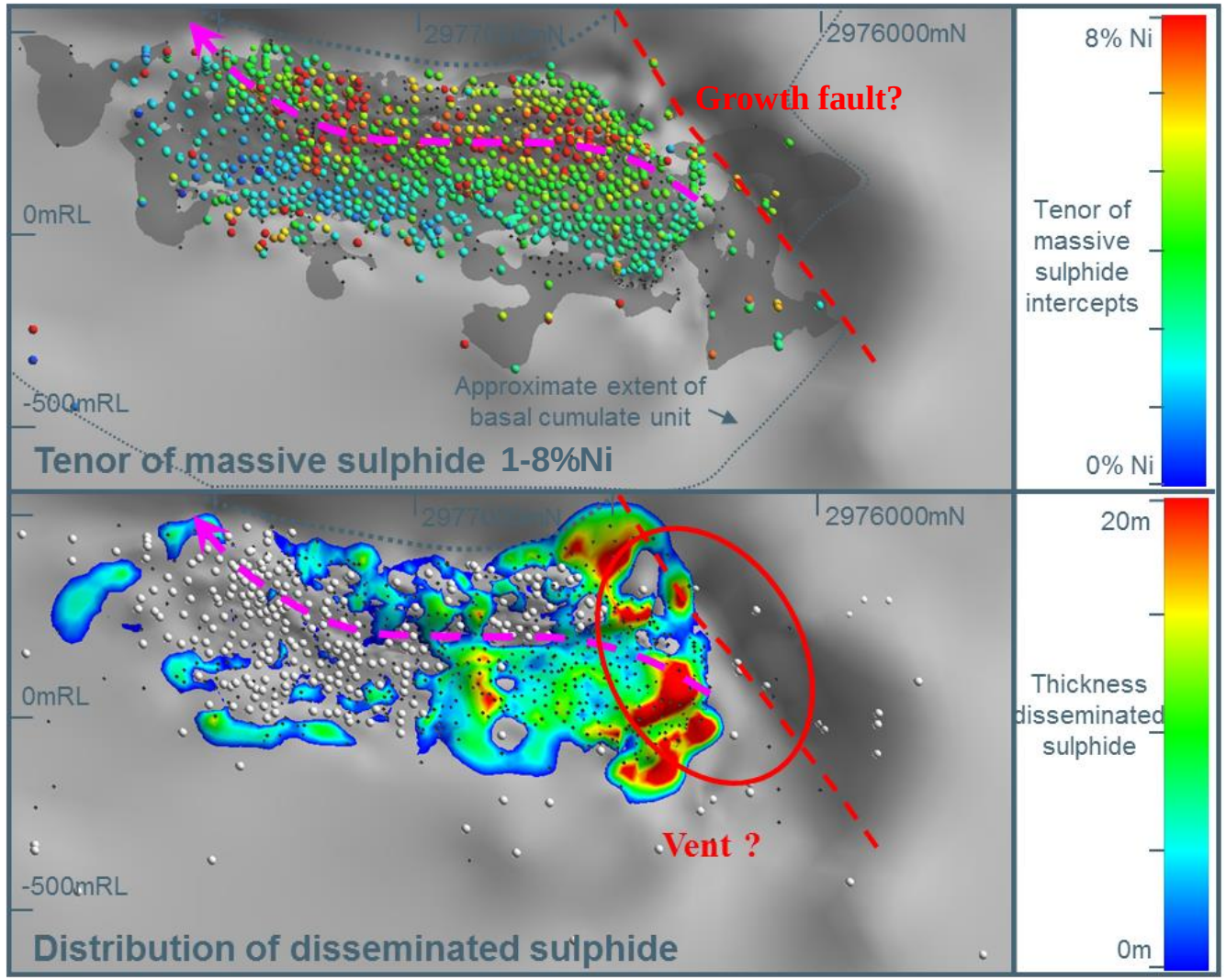
X corresponds to inner flank of bend in lava pathway (less dynamic conditions and eventual stagnation)

# Cliffs deposit: distal to rift axis, proximal to vent?

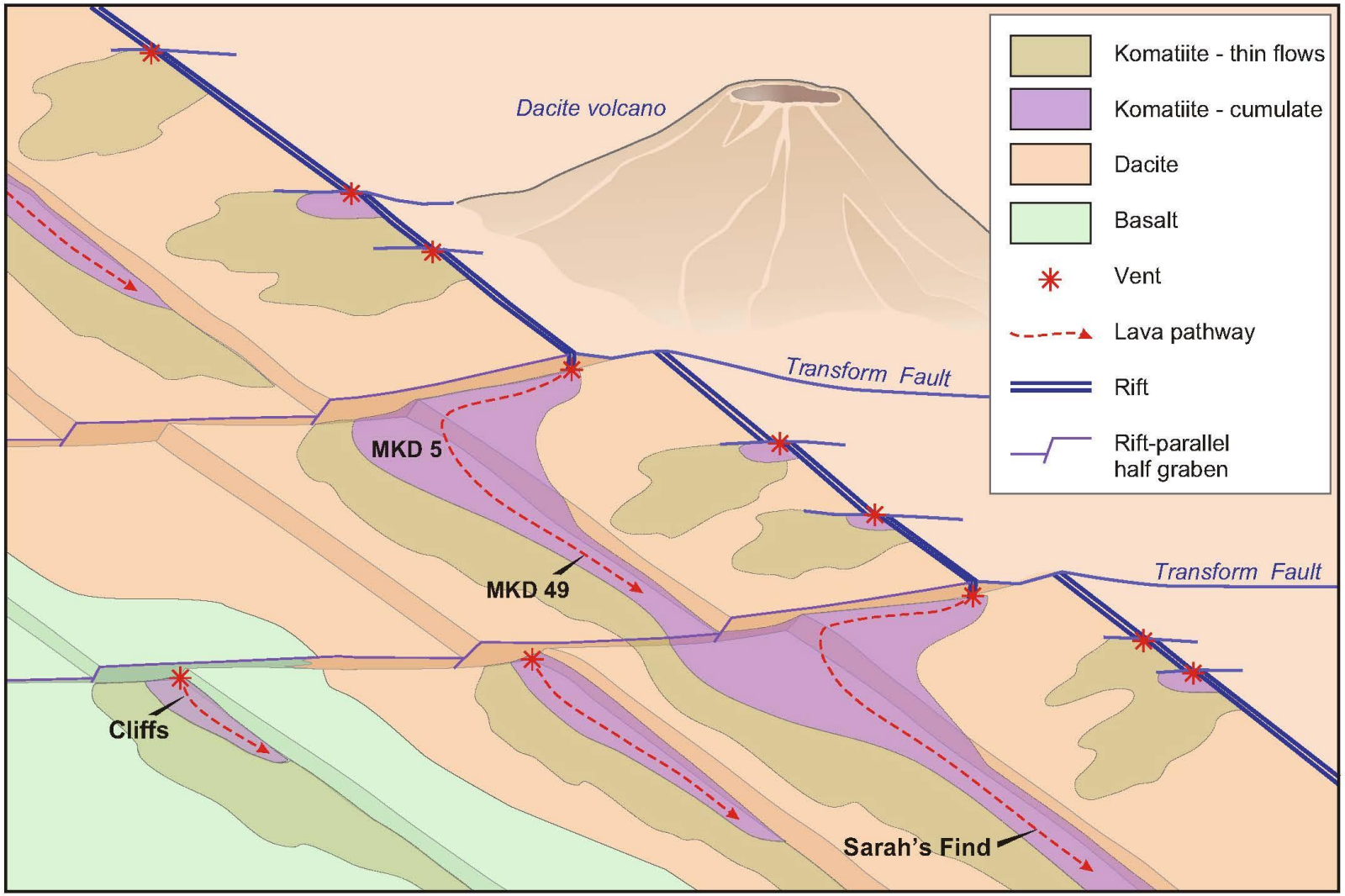
**Cliffs pathway**

- Meso-to orthocumulate.
- Typically <100m thick.
- Very different to Mt Keith or Perseverance.

Long section looking E



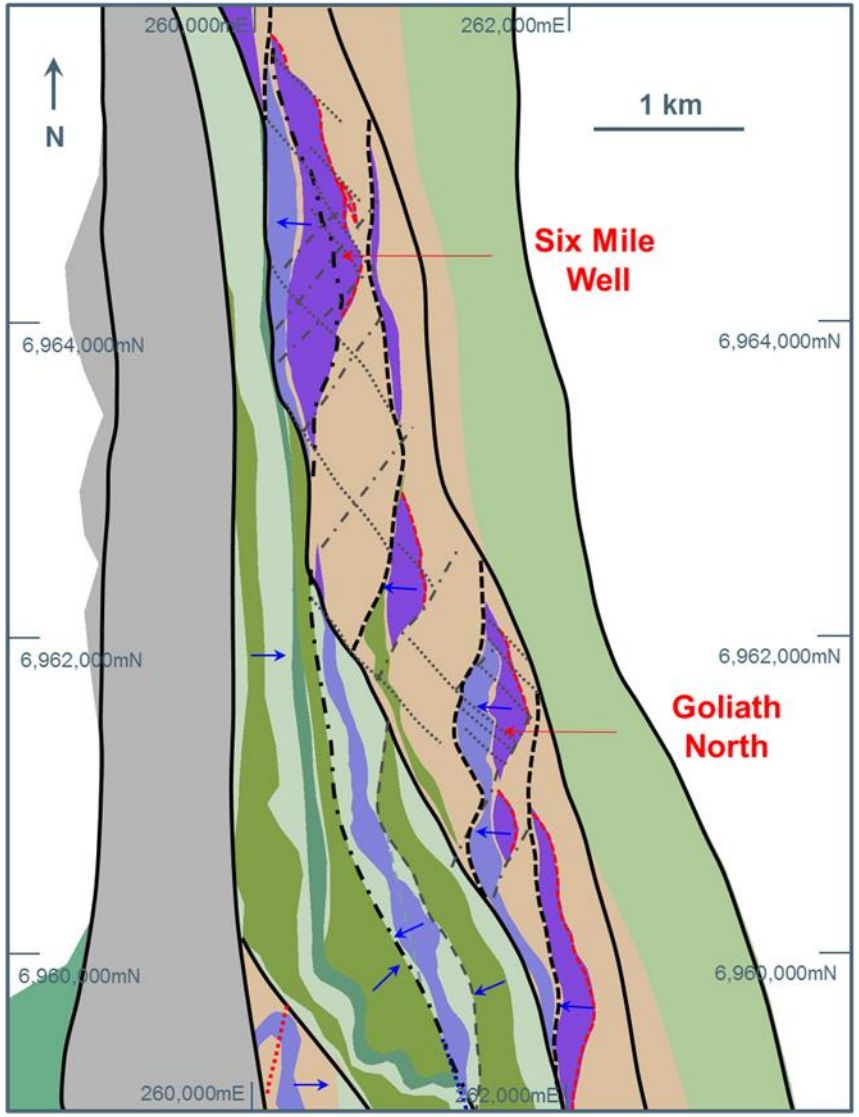
# Mt Keith domain - reconstruction



# Yakabindie domain: NW-trending zone

## Yakabindie pathways

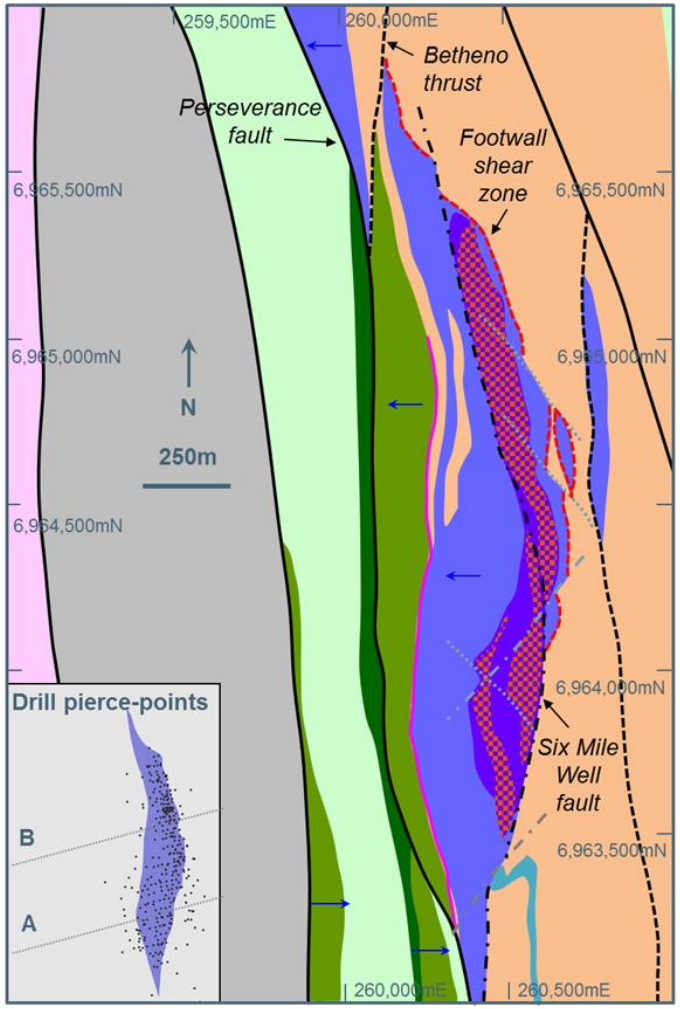
- Discrete cumulate lenses overlain by linked thin-flow sequences:
  - Now thrust-stacked.
- Footwall faults:
  - NNW-trending,
  - NNE-trending.
- Upper contact dips more steeply than basal contact:
  - Cumulate body thins rapidly with depth,
  - Both contacts match igneous layering,
  - Suggests footwall subsidence during volcanism,
  - FW faults are growth faults.

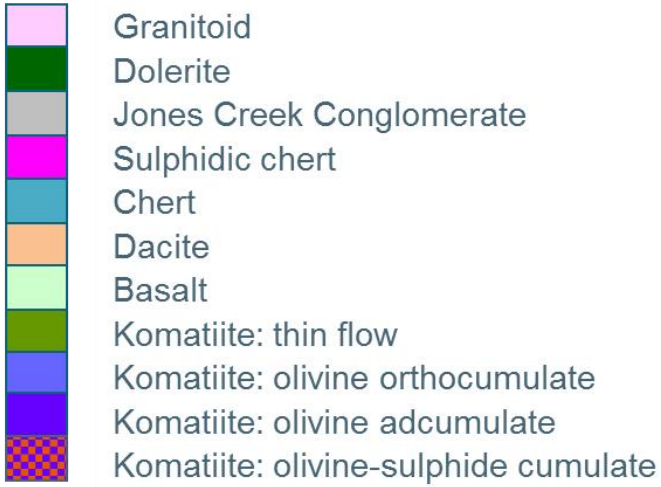



- Granitoid
- Gabbro
- Jones Creek Conglomerate
- Centenary Bore Basalt
- Komatiite: thin flows
- Komatiite: olivine orthocumulate-rich
- Komatiite: olivine adcumulate-rich
- Mt Keith Dacite
- McFarlane's Basalt
- NNW-trending dextral-reverse fault
- NE-trending dextral faults
- NW-trending sinistral faults
- Sinistral-reverse faults
- Synclinal axis
- Anticlinal axis
- Imbricate thrusts
- Growth faults
- Domain bounding faults
- Younging direction

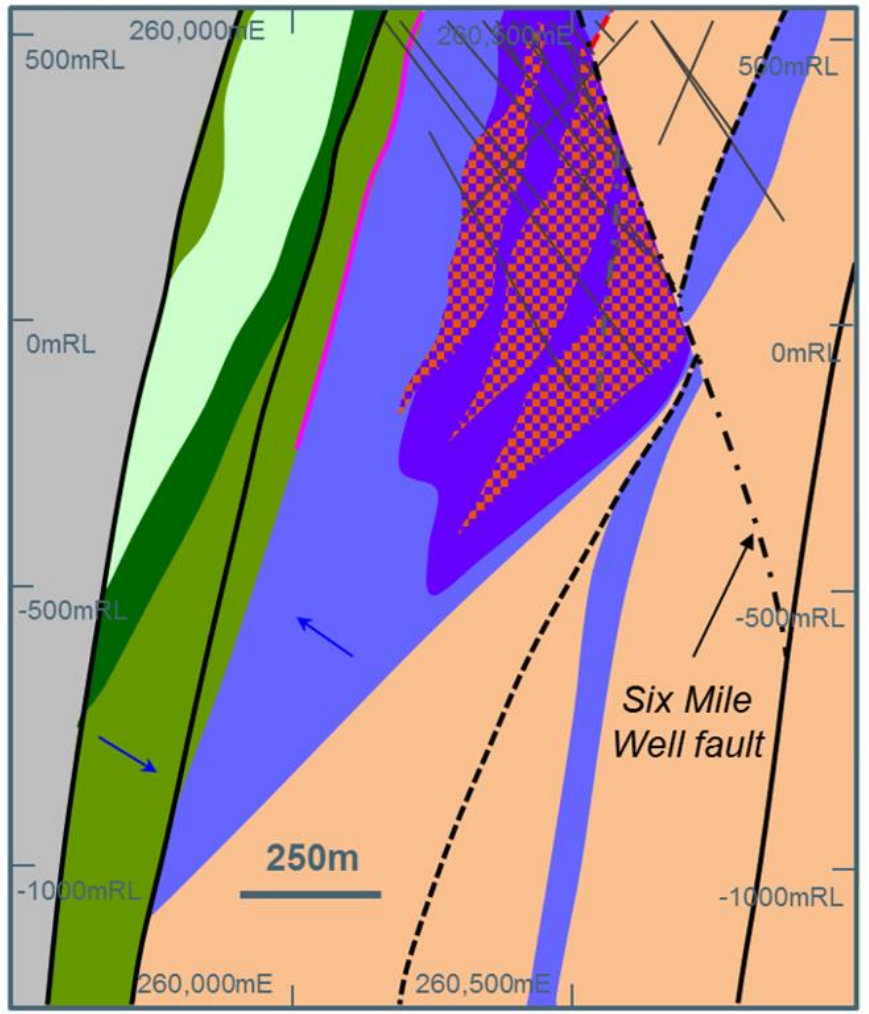
# Six Mile Well: limited extent of pathway

Plan view

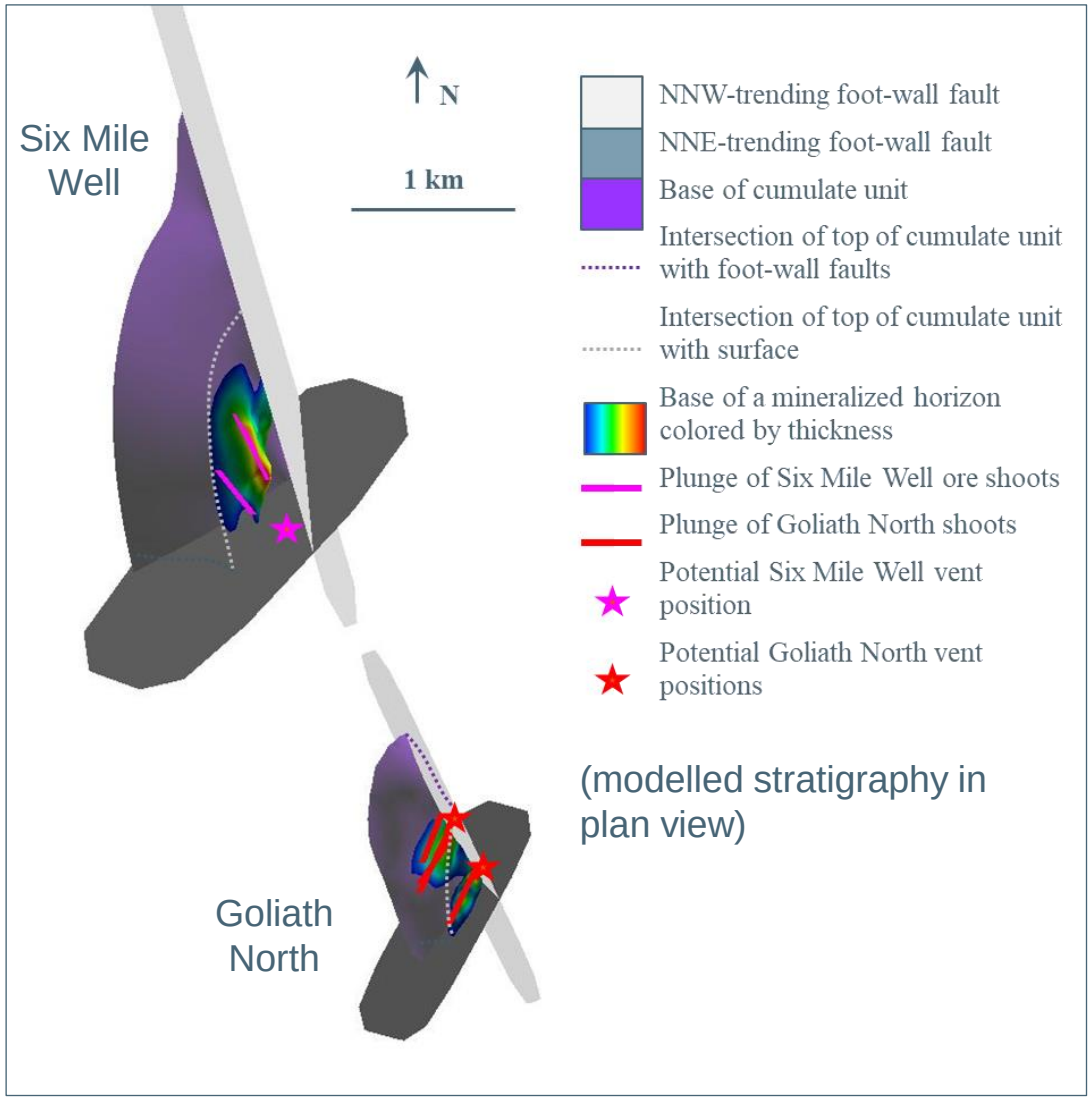


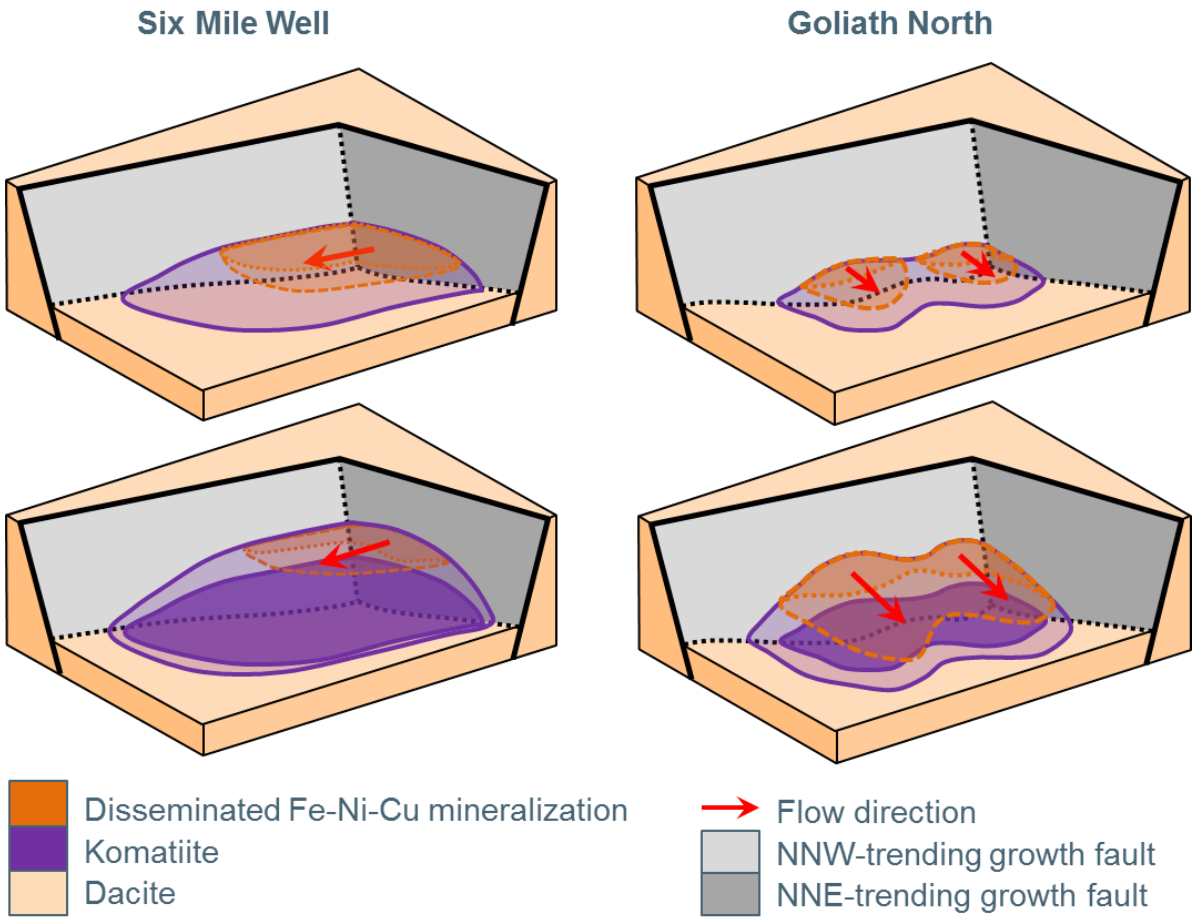




A: 6963740mN section looking NNW



# Yakabindie - reconstruction



# Controls on mineralisation

**NNW-trending segments of the AWB: Mt Keith & Perseverance**

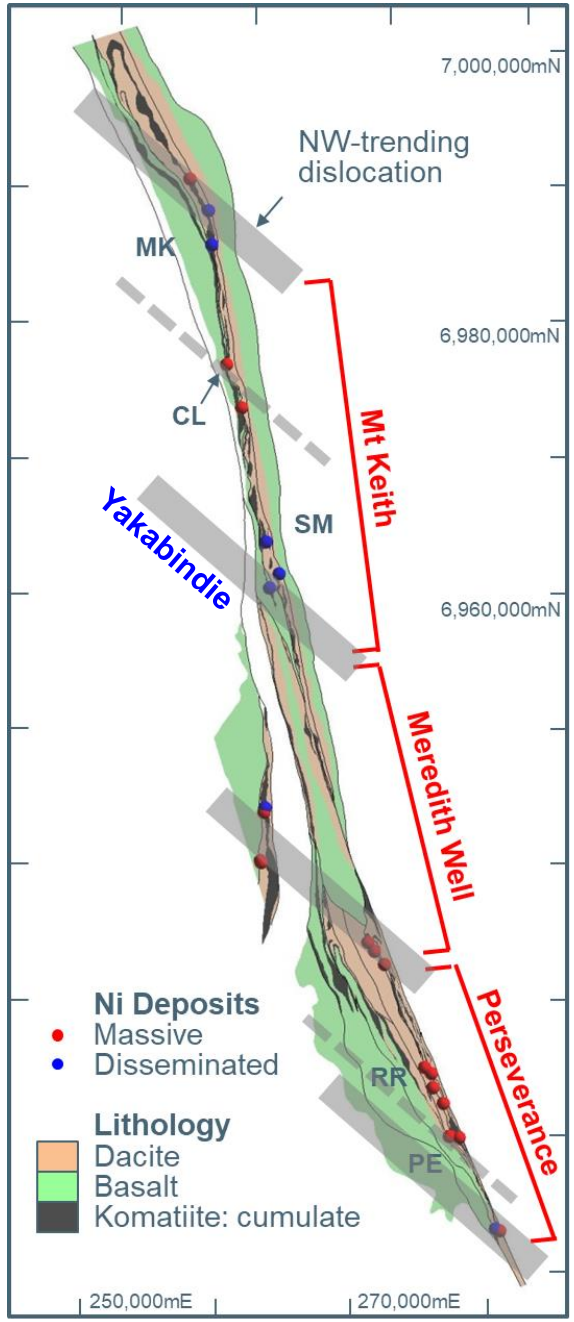
- Pathway positions >1.5km long, in sheeted bodies of olivine cumulate with >20km strike length.
- Volcanic grain was broadly NNE-trending.

**NW-trending corridors: Yakabindie**

- Pathway positions <0.5km long, in olivine cumulate bodies of limited areal extent.
- High-grade ore shoots trended both NNW and NE.

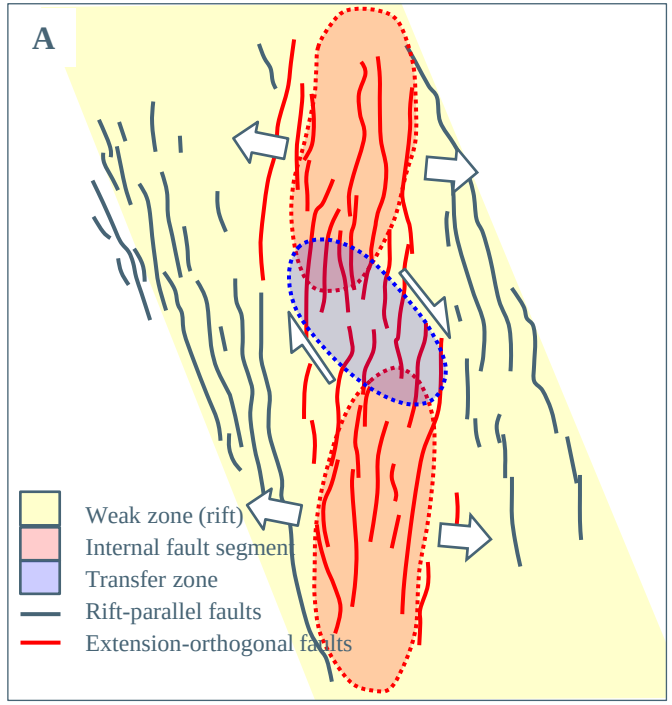
**Deposit-scale controls**

- Synvolcanic faults, particularly fault intersections.
- Bends in lava pathways.
- Vent proximity.

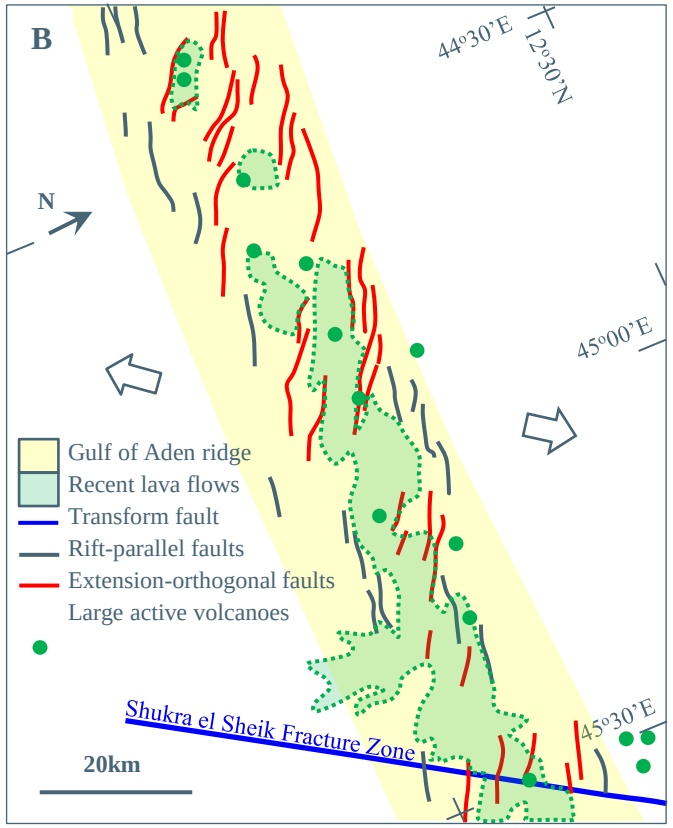


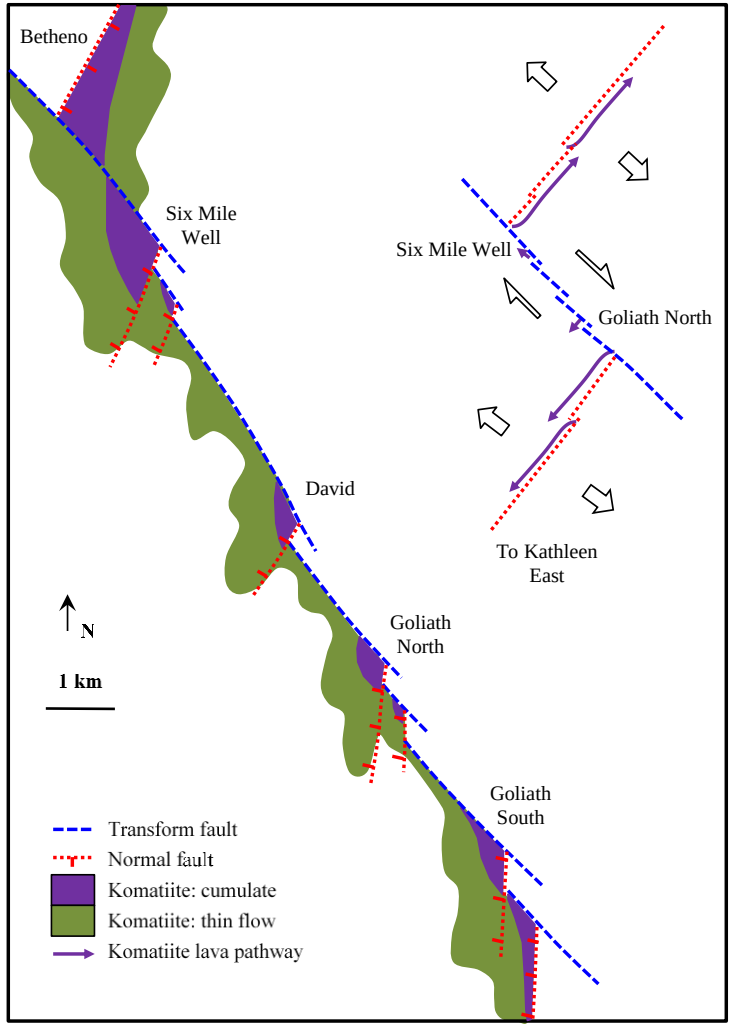
# Evidence for oblique extension?

Analogue model of oblique extension (after Corti, 2008)




Oblique extension in the Gulf of Aden (after Dauteuil et al., 2001)



# Conclusion: ~2.7 Ga volcanic architecture

**NNW-trending rift**

- Trend controlled by Eoarchaean craton margin.
- Three rift segments each ~30km in strike length.

**NNE-trending volcanic grain**

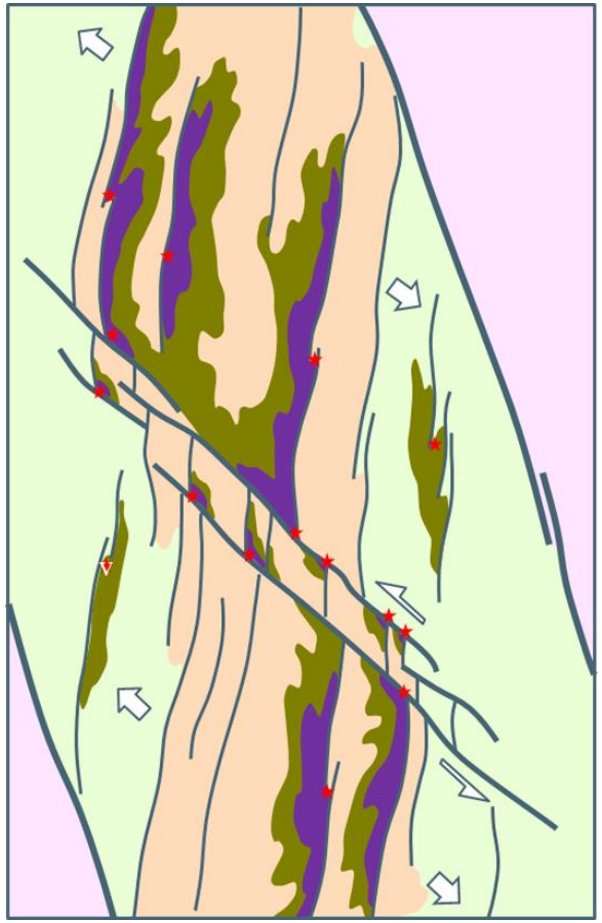
- Indicated by:
  - Orebody plunges,
  - NNE-trending growth faults.

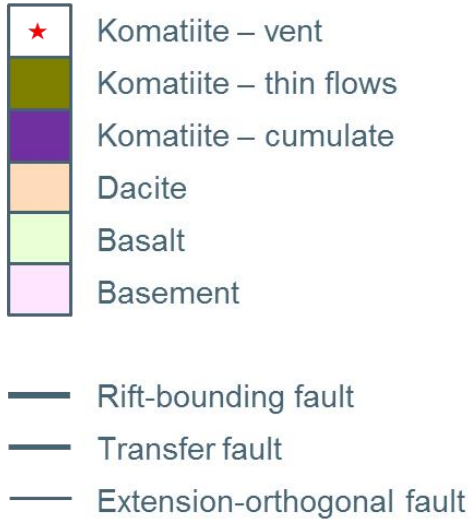
**NW-trending transfer zones**

- Marked by:
  - Sinistral jogs in domain-bounding faults,
  - Fold closures,
  - NW-trending accretionary structures & growth faults.

**Fe-Ni-Cu Deposits**

- Majority lie close to transfer zones.





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