Australia's National Science Agency

Interrogating Archean Domes

Insights From Barcoded Magmatic Stratigraphy and 3D Modelling

CSIRO – Wyloo Metals (Mincor Resources)

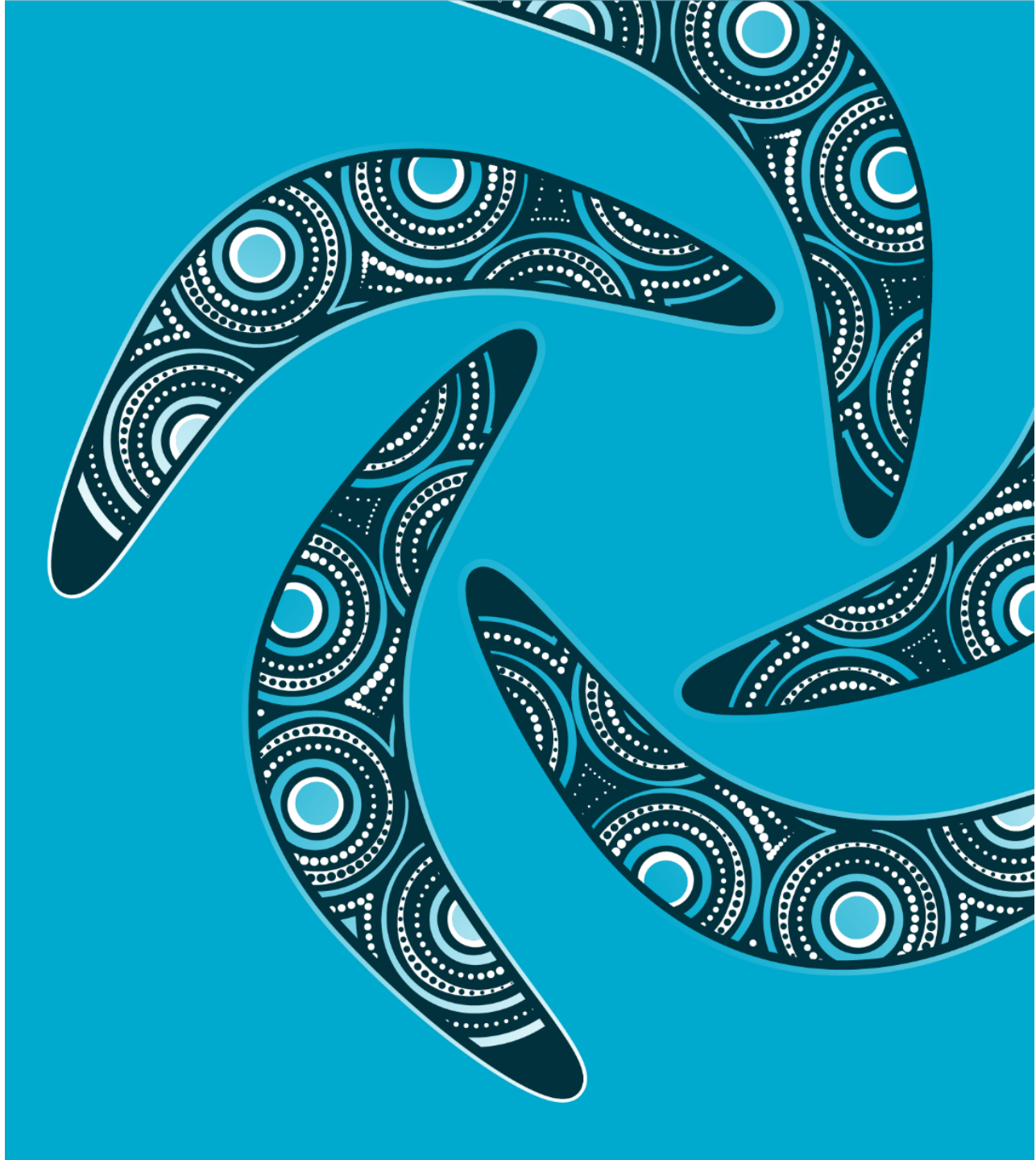
Helen McFarlane, Peter Schaubs, Catherine Spaggiari,
Margaux Le Vaillant and Steve Barnes | 9 April 2025

WYLOO METALS

Formerly MINCOR RESOURCES NL

I would like to begin by acknowledging the Whadjuk people of the Noongar Nation as the Traditional Owners of the land that we're meeting on today and pay my respect to their Elders past and present.

I also like to acknowledge the Malpa people as the Traditional Owners of the lands on which this study occurred.



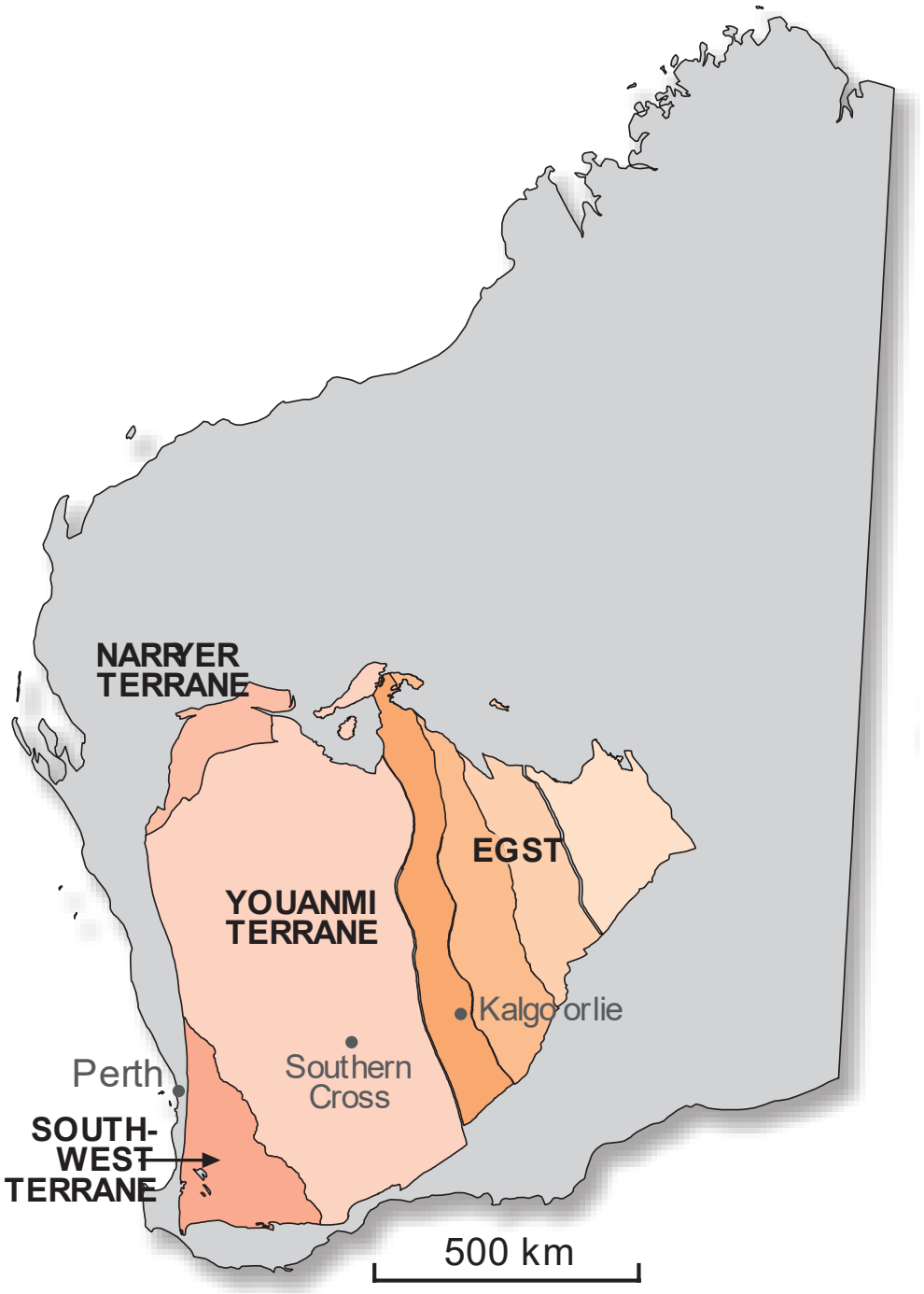
Polyphase magmatism vs polyphase deformation

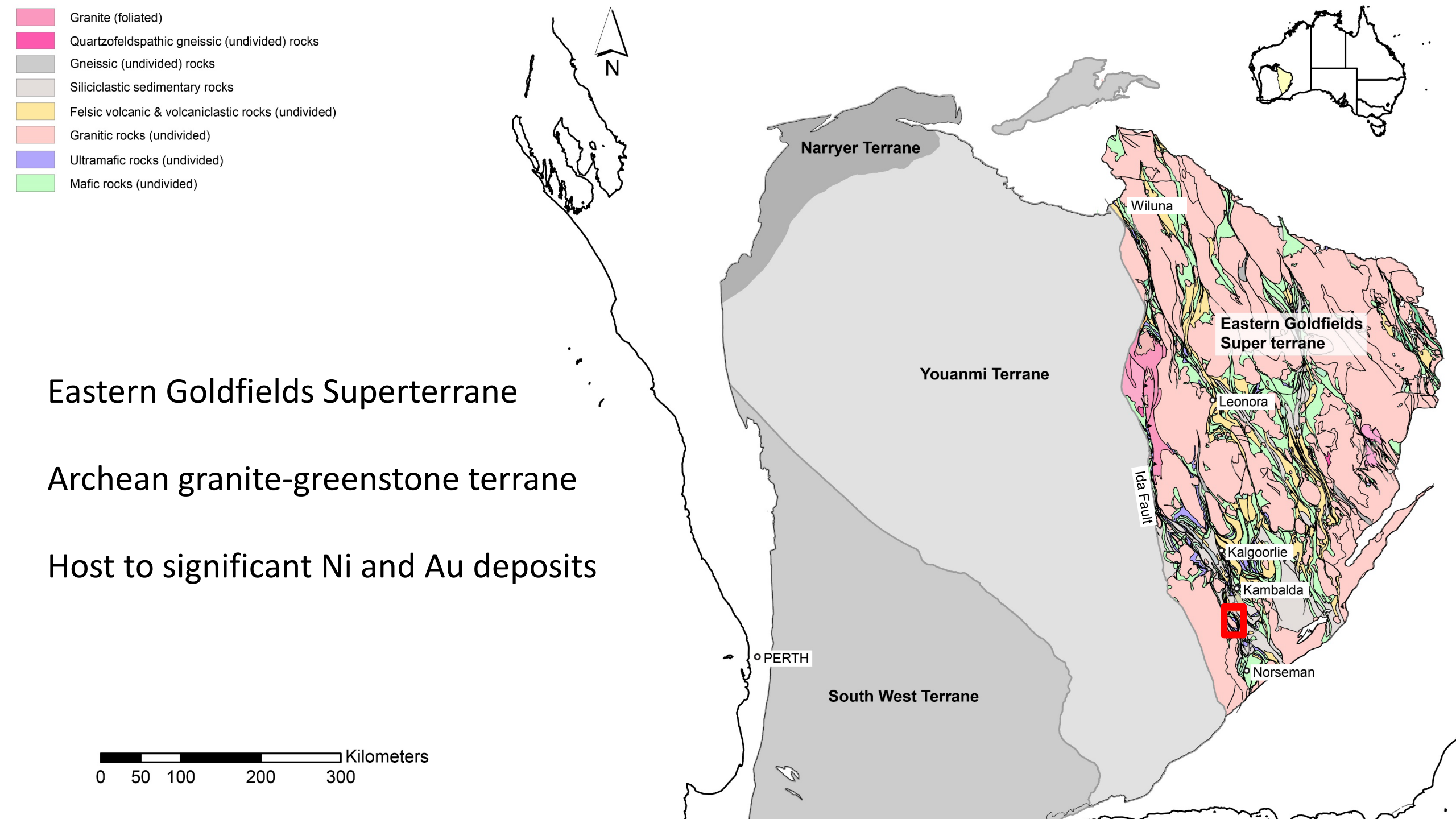
Magmatic and orogenic mineralising processes

Archean domes and ~~surrounding~~ encircling debates

Sagduction vs subduction

Strong opinions

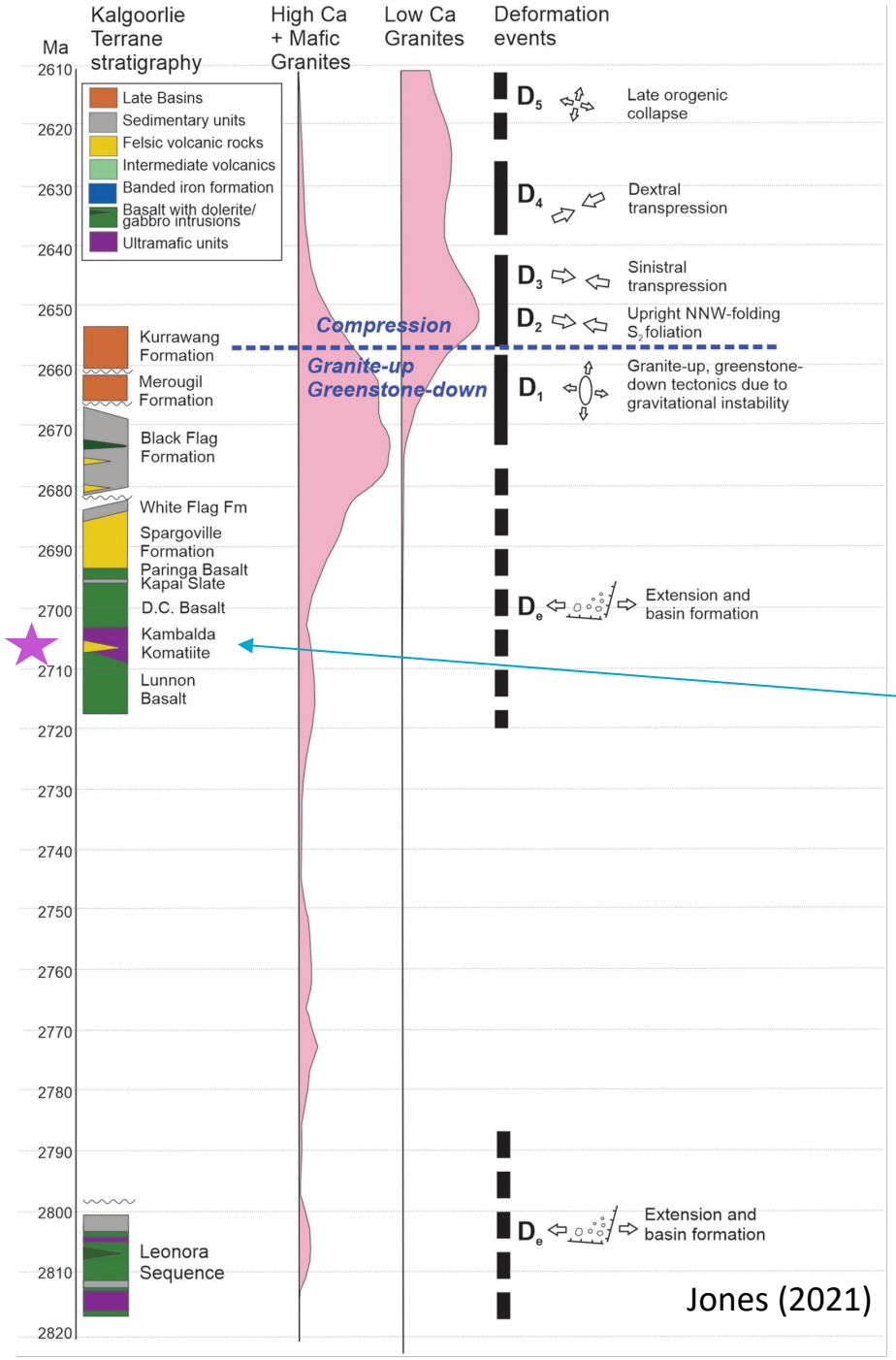




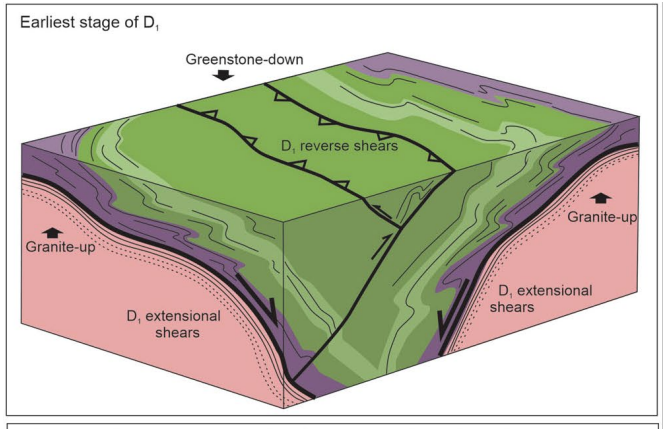
Eastern Goldfields Superterrane

Archean granite-greenstone terrane

Host to significant Ni and Au deposits



Jones (2021)



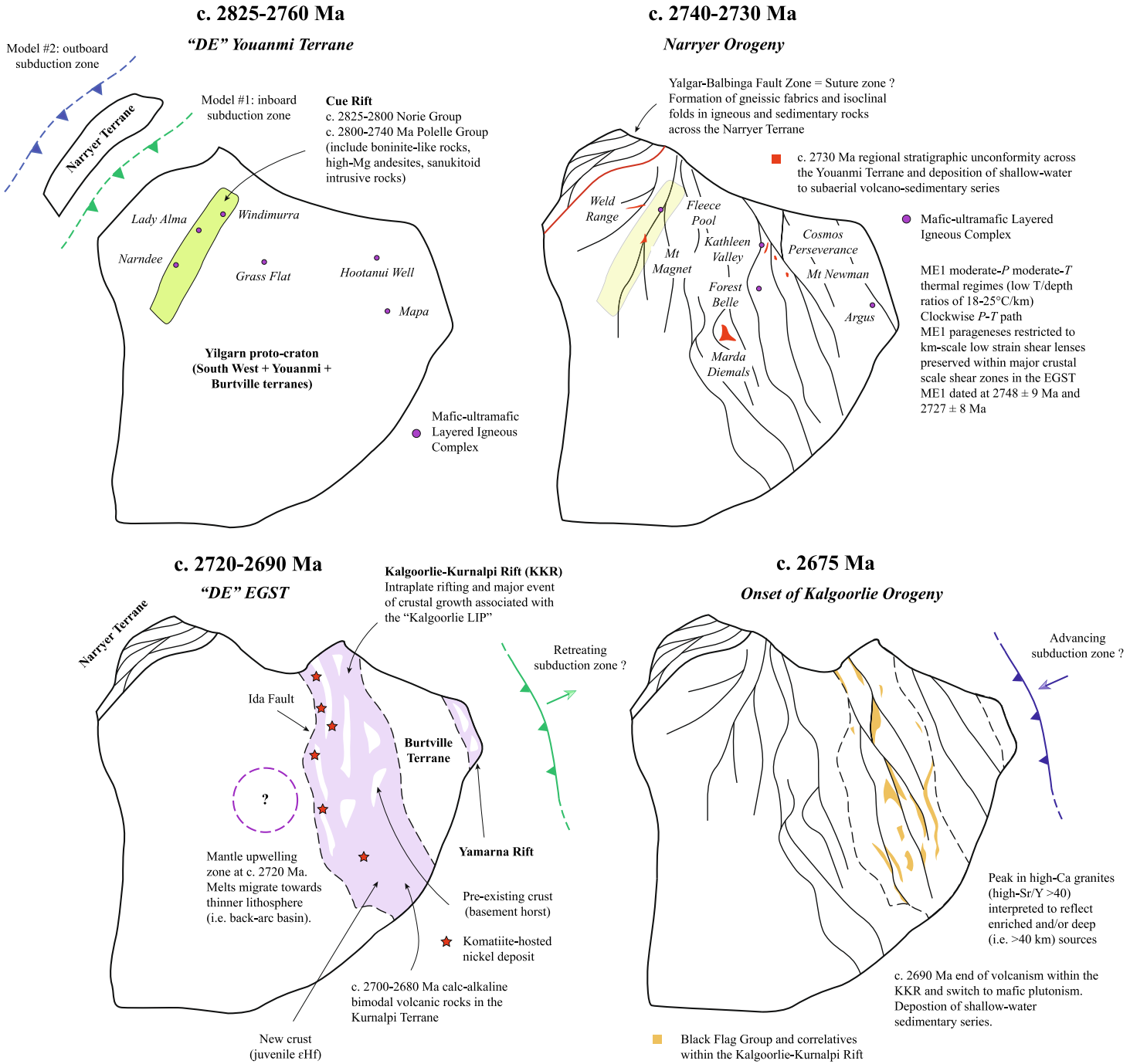
Jones (2021)

Greenstone belt stratigraphy between Norseman and Wiluna

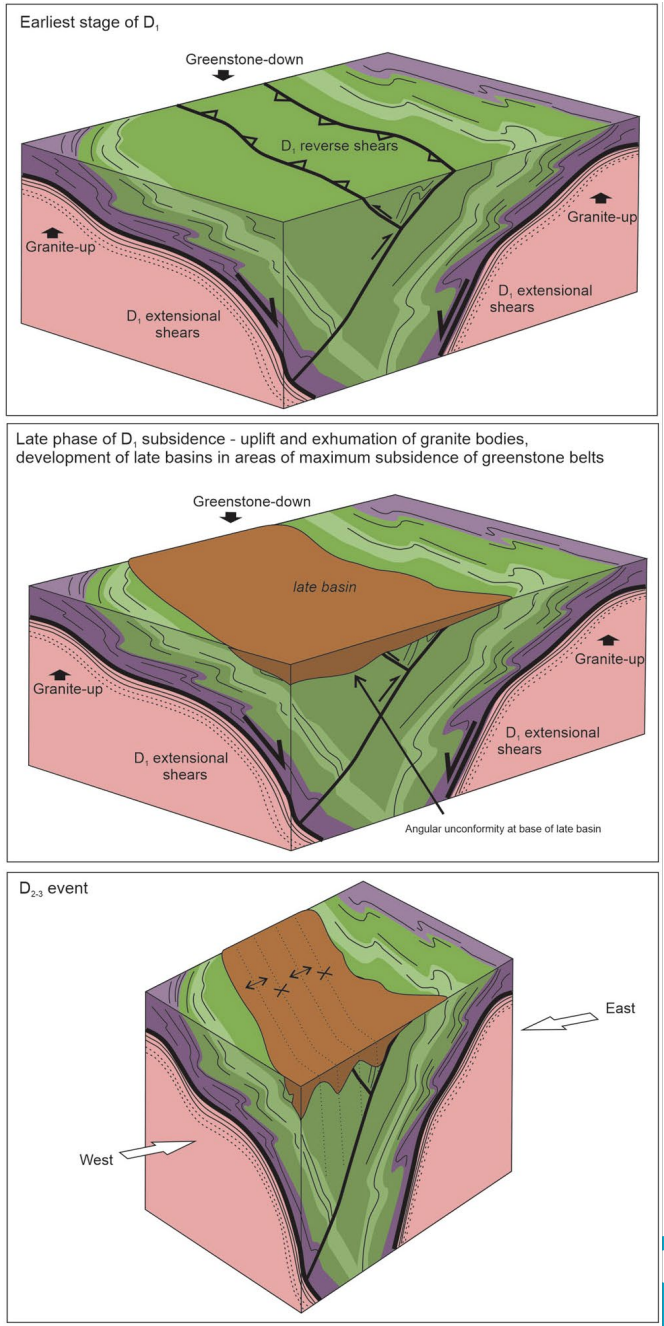
Kalgoorlie Group mafic-ultramafic packages including:

- Hannans Subgroup ('Kambalda sequence'; c. 2720-2690 Ma)
- Coolgardie Subgroup

Locally overlie poorly known, >2800 Ma mafic-ultramafic rocks

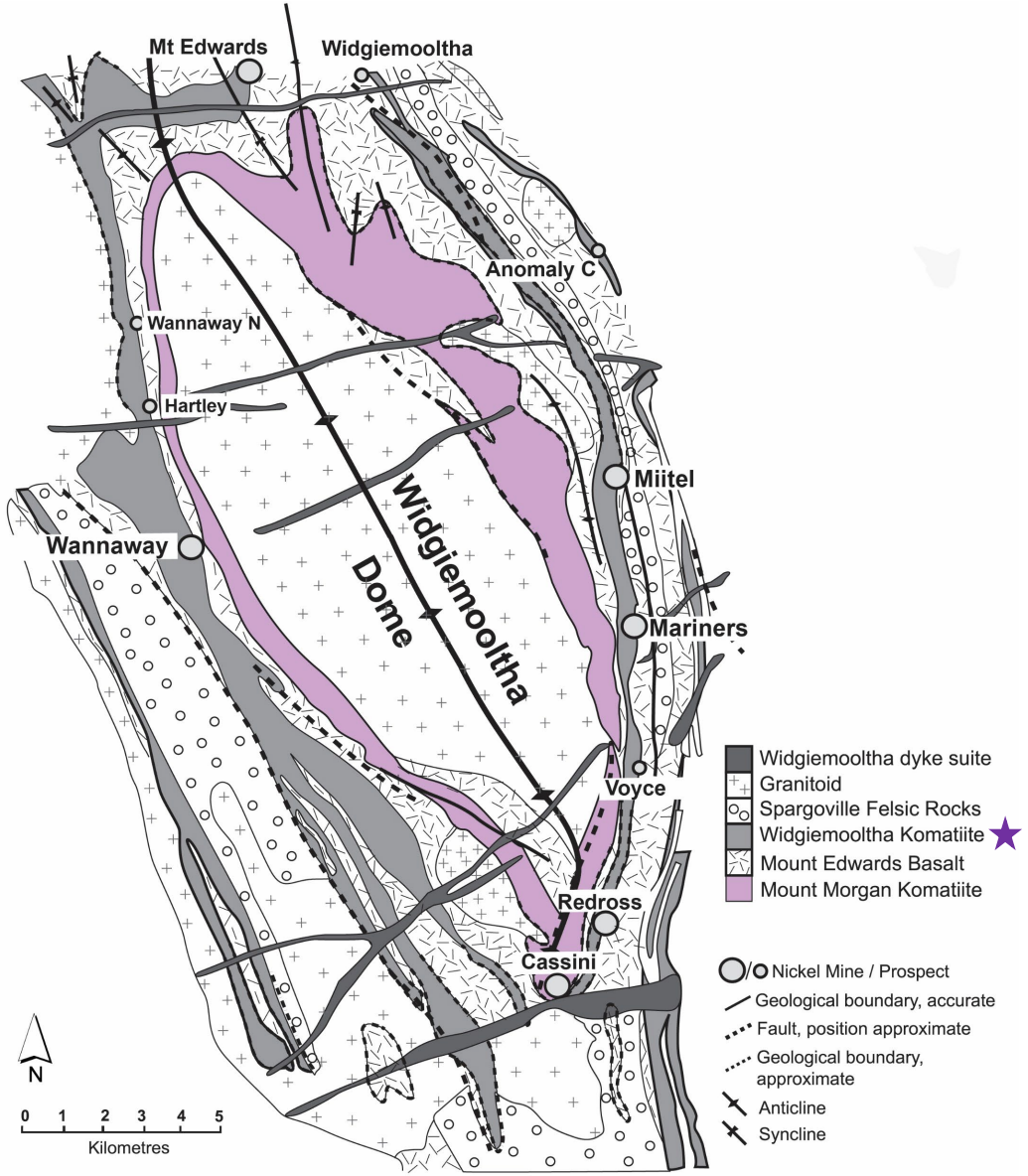


Masurel and Thebaud (2024)

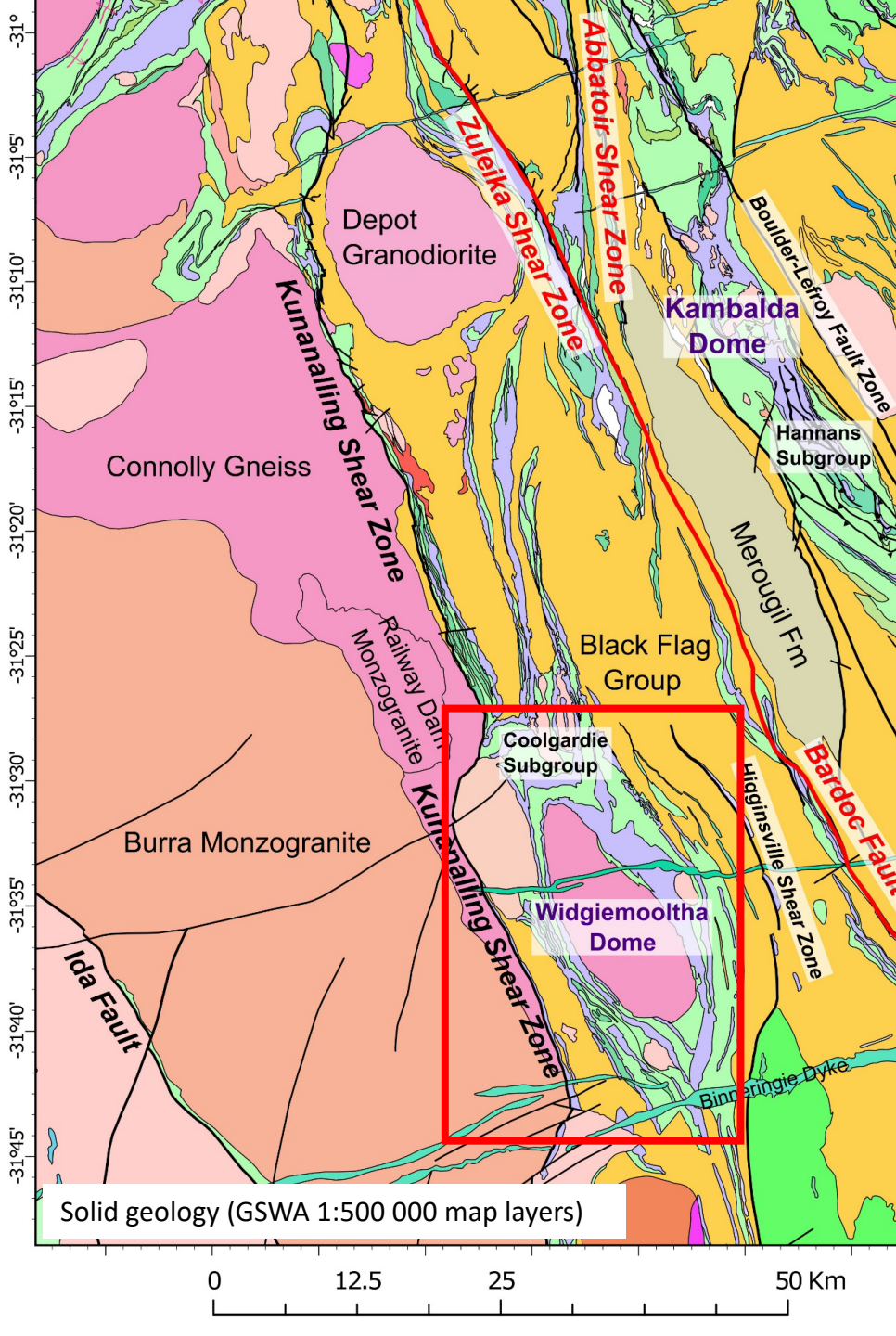


Jones (2021)

Widgiemooltha Dome



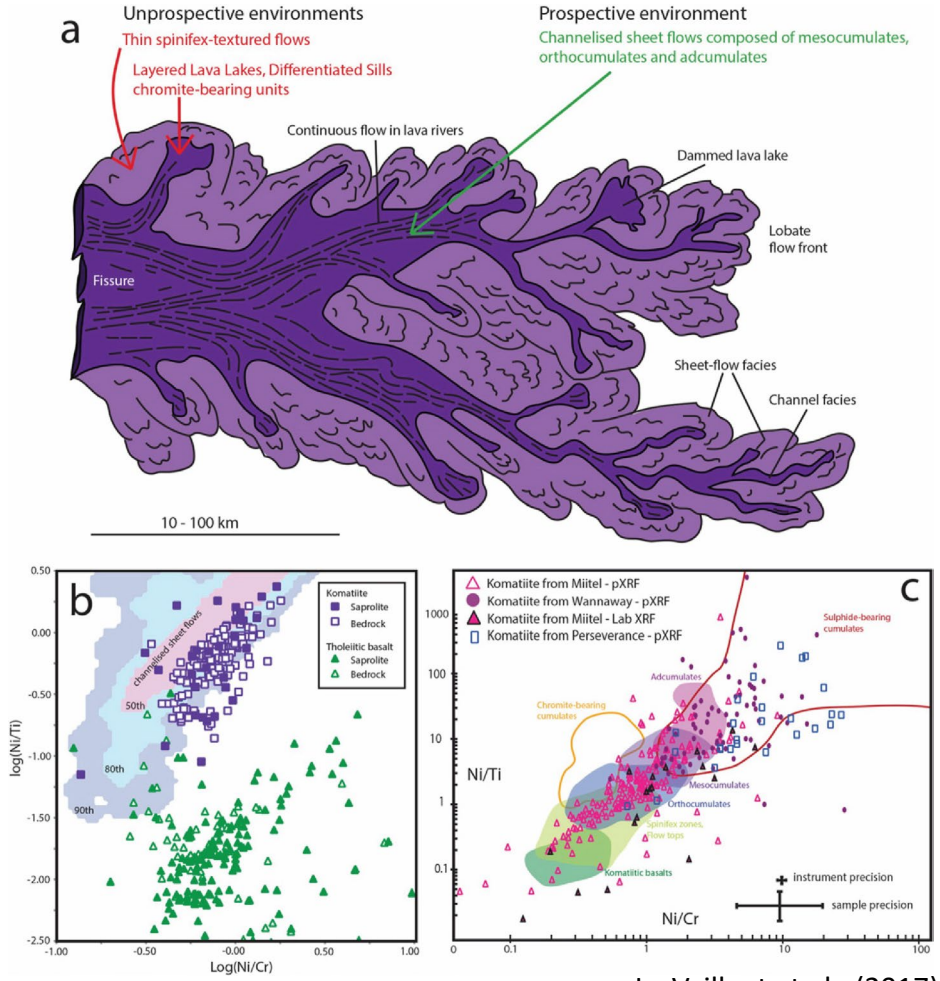
Seat et al., (2004)



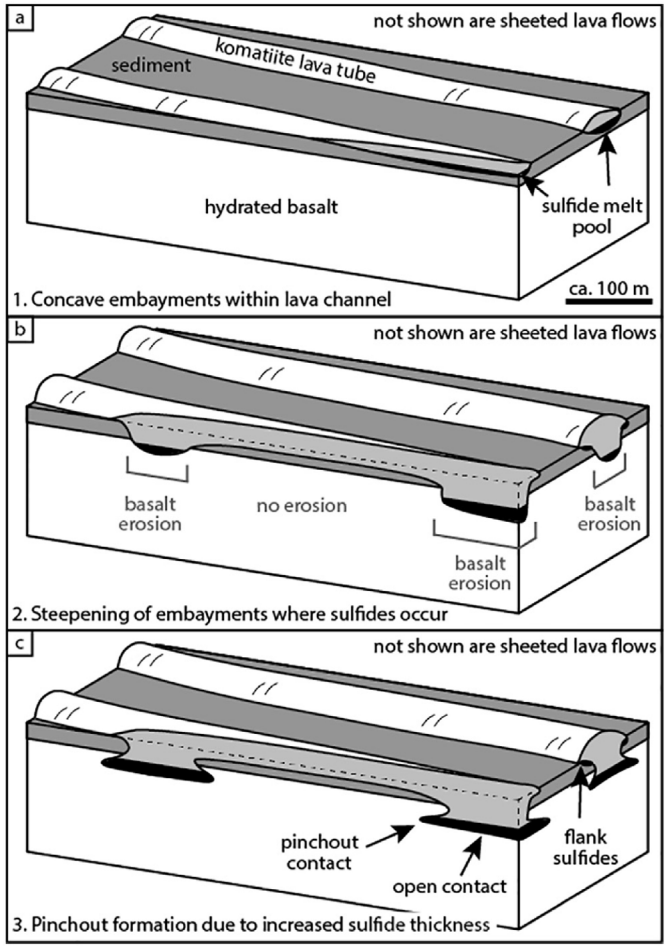
Komatiite-associated Ni sulfide systems

Distinct morphology, textures and geochemistry

- High MgO mantle-derived ultramafic lava flows
- Use of Ni/Ti vs Ni/Cr to delineate favourable volcanic environments



Le Vaillant et al., (2017)

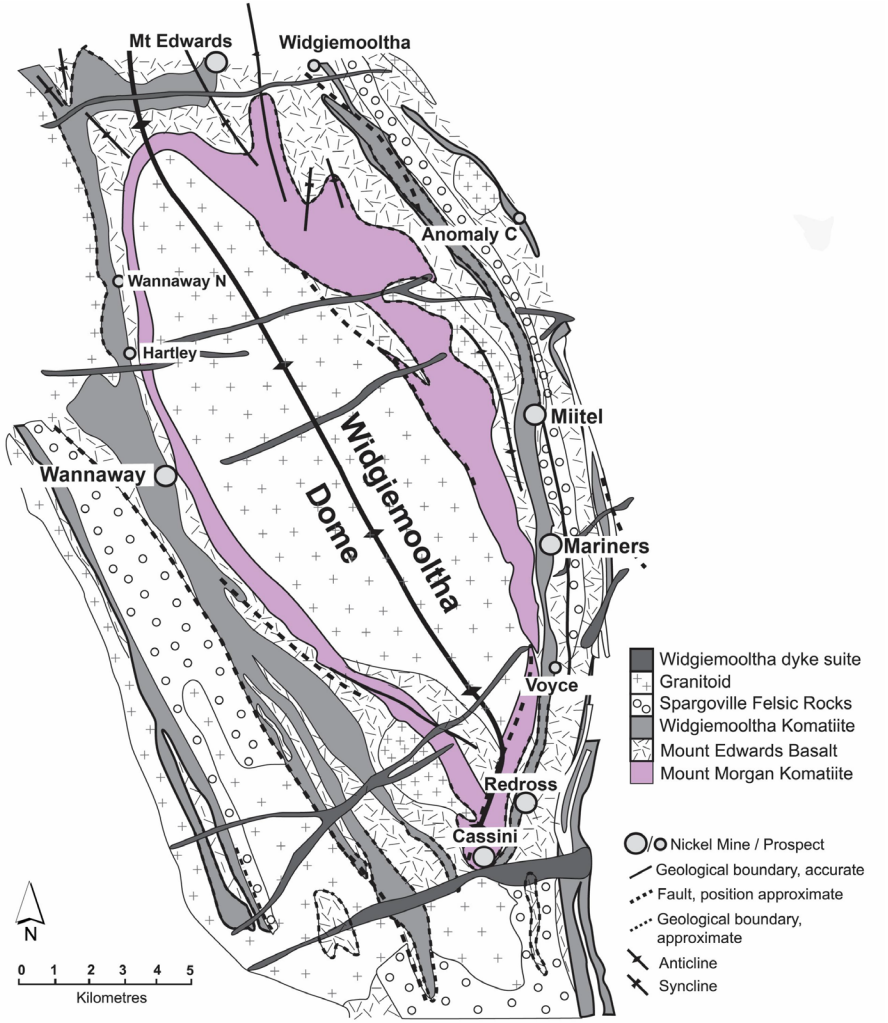


Staude et al., (2017)

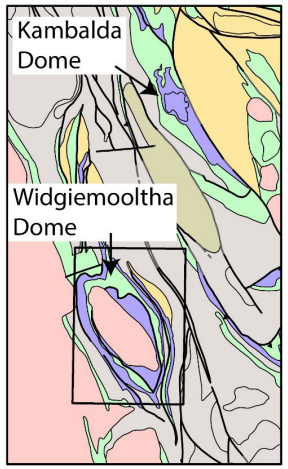
Key questions

- Can we refine the stratigraphy of the Widgiemooltha Dome and host komatiite sequences?
- Can we better constrain the subsurface geometries and improve our understanding of the structural evolution of the dome?
- What are the implications for the stratigraphic, volcanogenic and structural controls of Ni mineralisation?

Challenges to 3D geological modelling

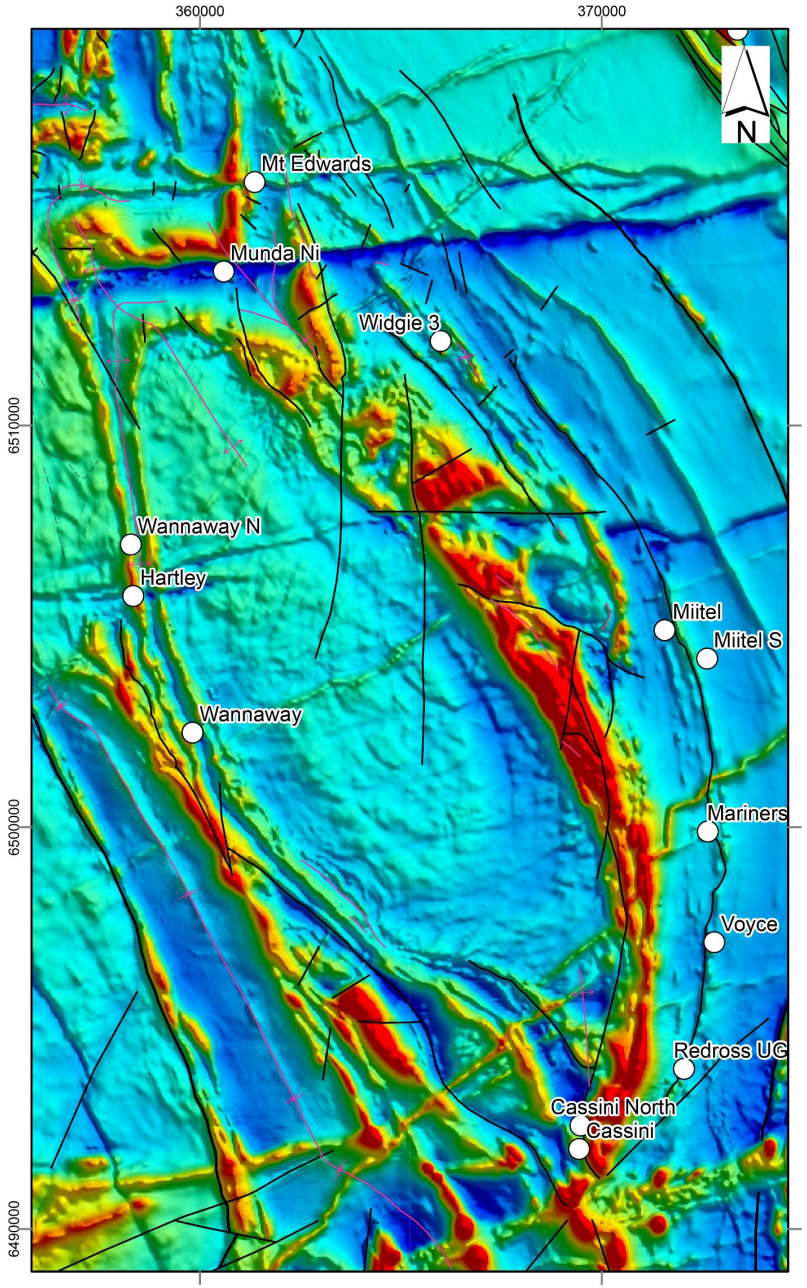


- Poor understanding of the stratigraphy and lithological order due to limited outcrop
- Complex, polyphase deformation history
- Few phases to directly date
- Few younging indicators
- No clear marker horizons for displacement
- Strong rheological contrasts between units
  - ➢ basalt, komatiite, semi-massive and massive sulfides
- Need to include drilling information



Legend

- Mineralization_sites_nick
- Fault; exposed
- Shear zone, major; exposed
- Fold axial trace; exposed
- Fold axial trace; anticline, exposed
- Fold axial trace; syncline, exposed
- Trend of layering or foliation, unspecified

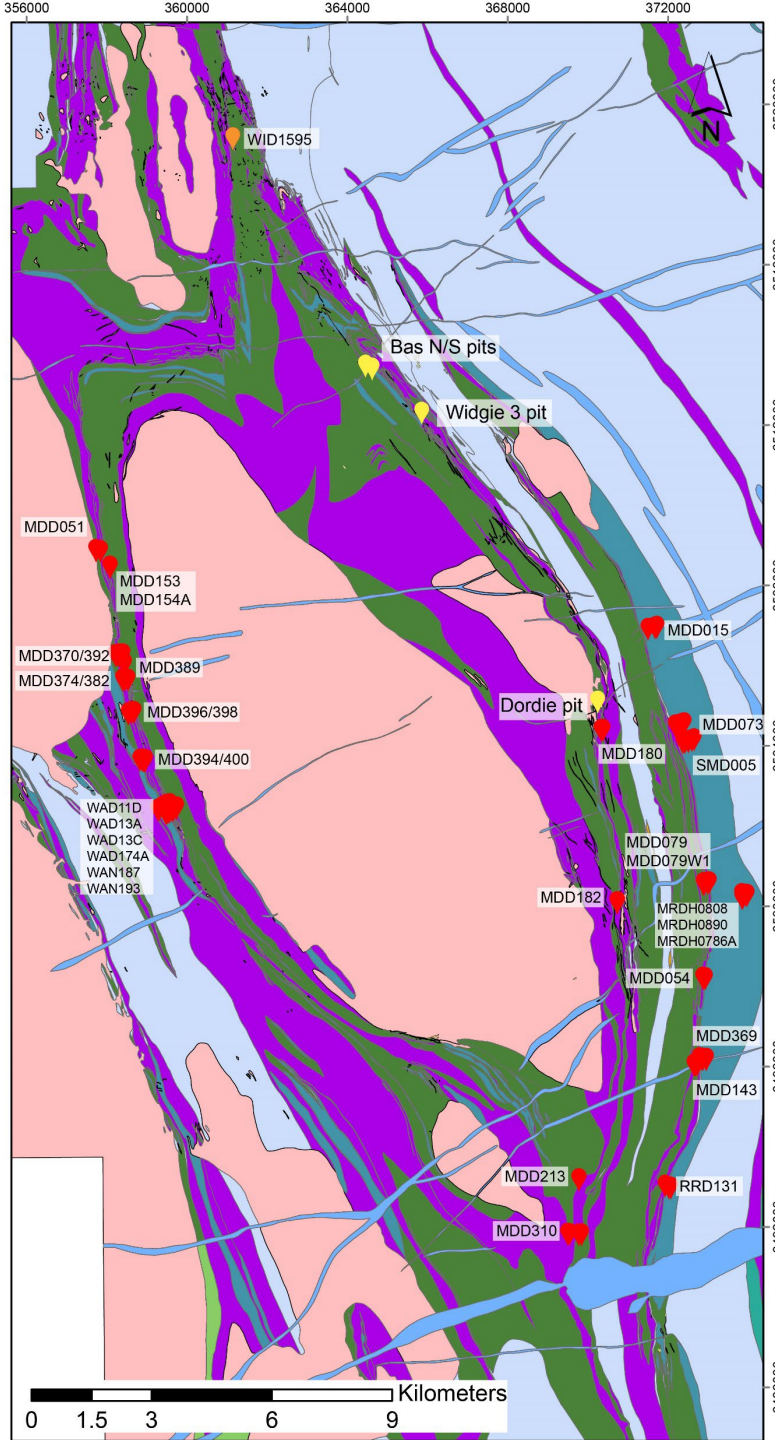


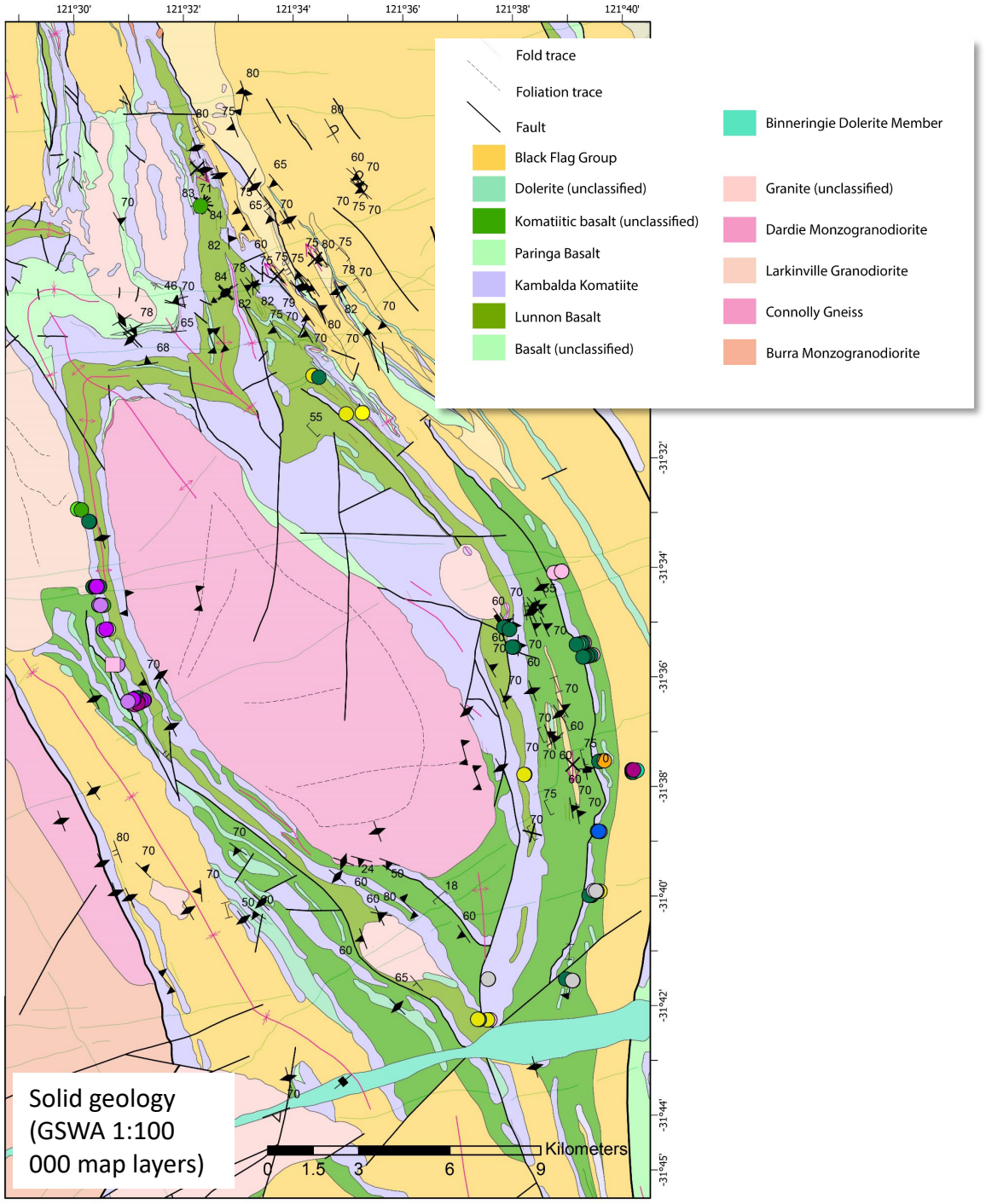
Legend

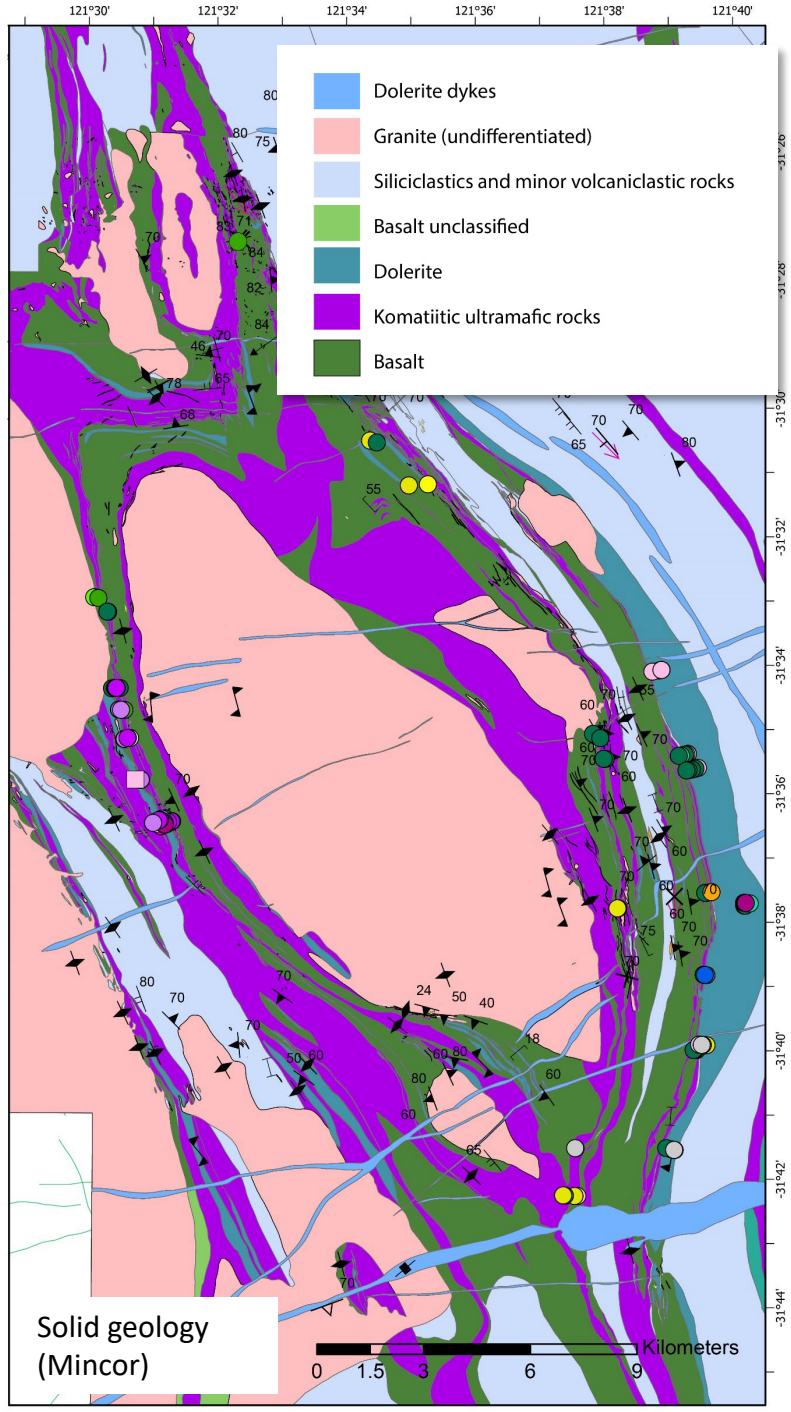
- DDH samples
- WID1595
- Pit locations

Mincor lithology

- Felsic intrusive rock
- Felsic volcanic rock
- Quartz veins
- Granitoids
- Mafic dyke
- High MgO basalts
- Mafic intrusive rock
- Komatiite flows
- Basalts
- Lunnon Basalt, Basalts
- Black Flag Group and equivalents

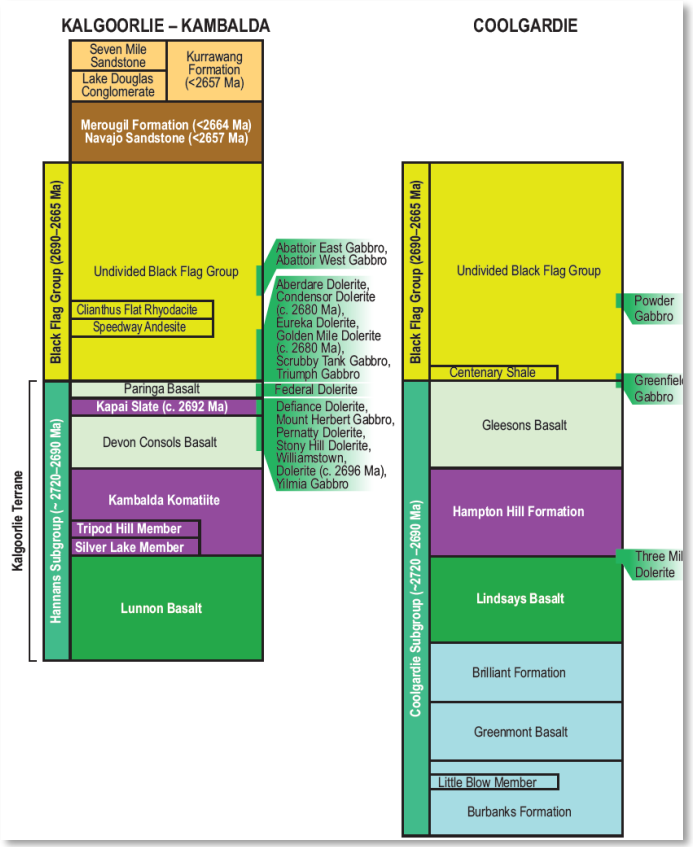



121°30'
121°32'
121°34'
121°36'
121°38'
121°40'
-31°32'
-31°34'
-31°36'
-31°38'
-31°40'
-31°42'
-31°44'
-31°45'
Fold trace
Foliation trace
Fault
Black Flag Group
Dolerite (unclassified)
Komatiitic basalt (unclassified)
Paringa Basalt
Kambalda Komatiite
Lunnon Basalt
Basalt (unclassified)
Binneringie Dolerite Member
Granite (unclassified)
Dardie Monzogranodiorite
Larkinville Granodiorite
Connolly Gneiss
Burra Monzogranodiorite
WAROX_Structures
Bedding; inclined, overturned/inclined, vertical
Cleavage; vertical, inclined
Igneous layering; inclined
Foliation; vertical, inclined
Fold; synform, antiform
Solid geology (GSWA 1:100 000 map layers)
0 1.5 3 6 9
Kilometers

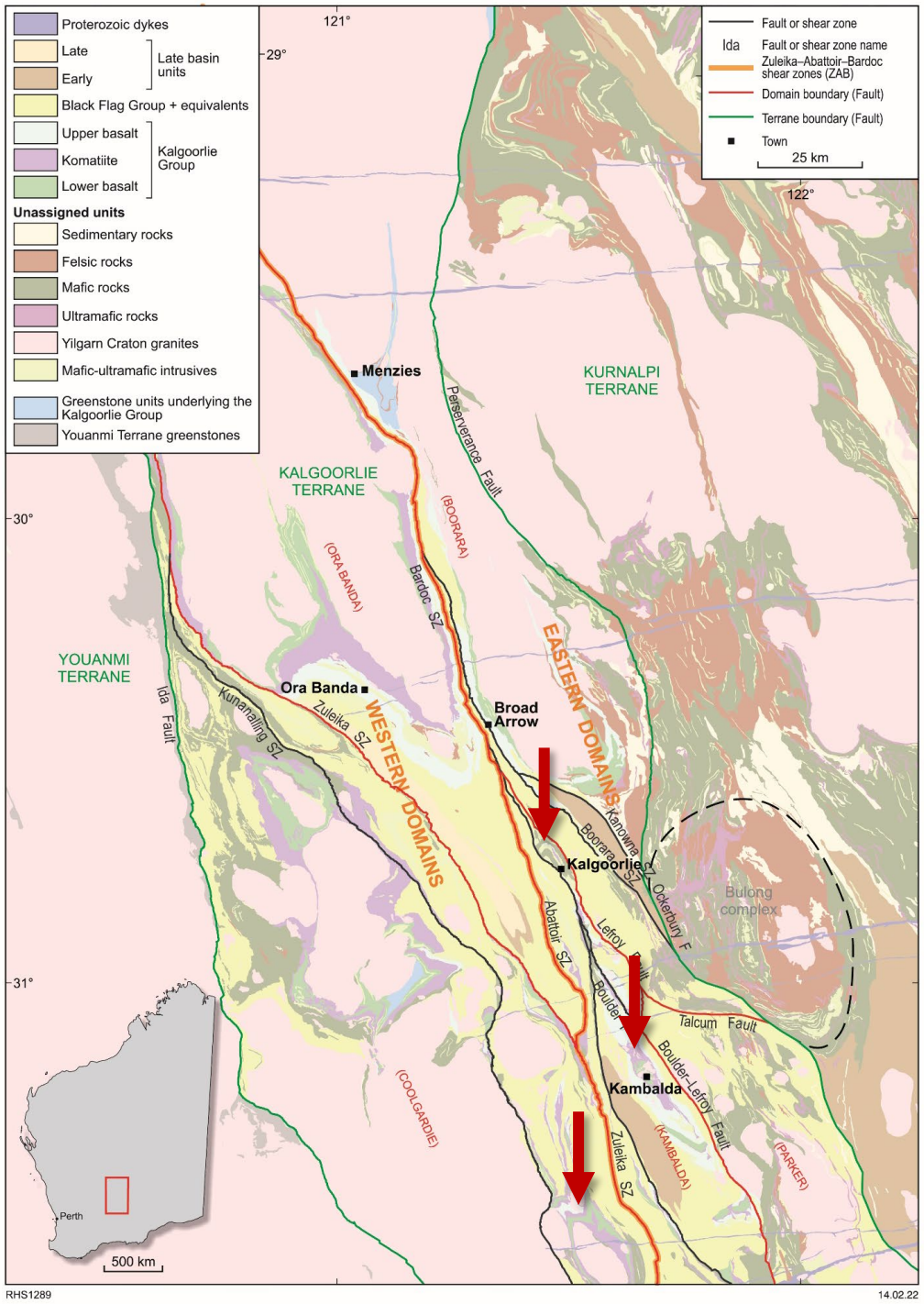

121°30'
121°32'
121°34'
121°36'
121°38'
121°40'
-31°32'
-31°34'
-31°36'
-31°38'
-31°40'
-31°42'
-31°44'
Dolerite dykes
Granite (undifferentiated)
Siliciclastics and minor volcaniclastic rocks
Basalt unclassified
Dolerite
Komatiitic ultramafic rocks
Basalt
WAROX_Structures
Bedding; inclined, overturned/inclined, vertical
Cleavage; vertical, inclined
Igneous layering; inclined
Foliation; vertical, inclined
Fold; synform, antiform
Solid geology (Mincor)
0 1.5 3 6 9
Kilometers

Magmatic stratigraphy

Mafic-ultramafic stratigraphy difficult to date and (formerly) difficult to geochemically distinguish



Smithies et al., (2022) GSWA Report

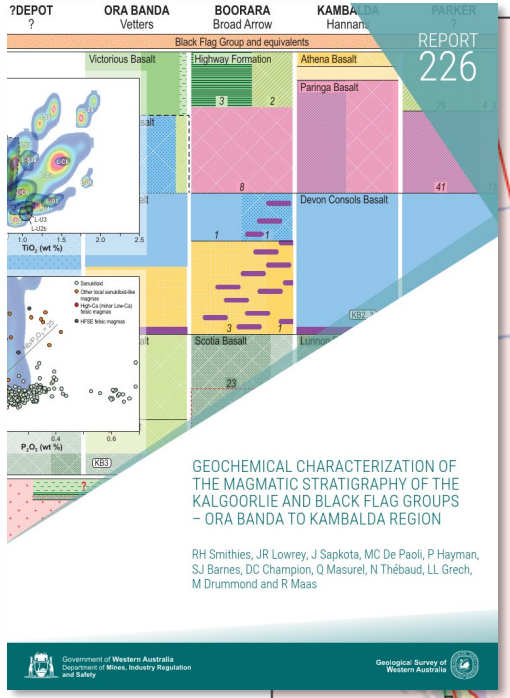


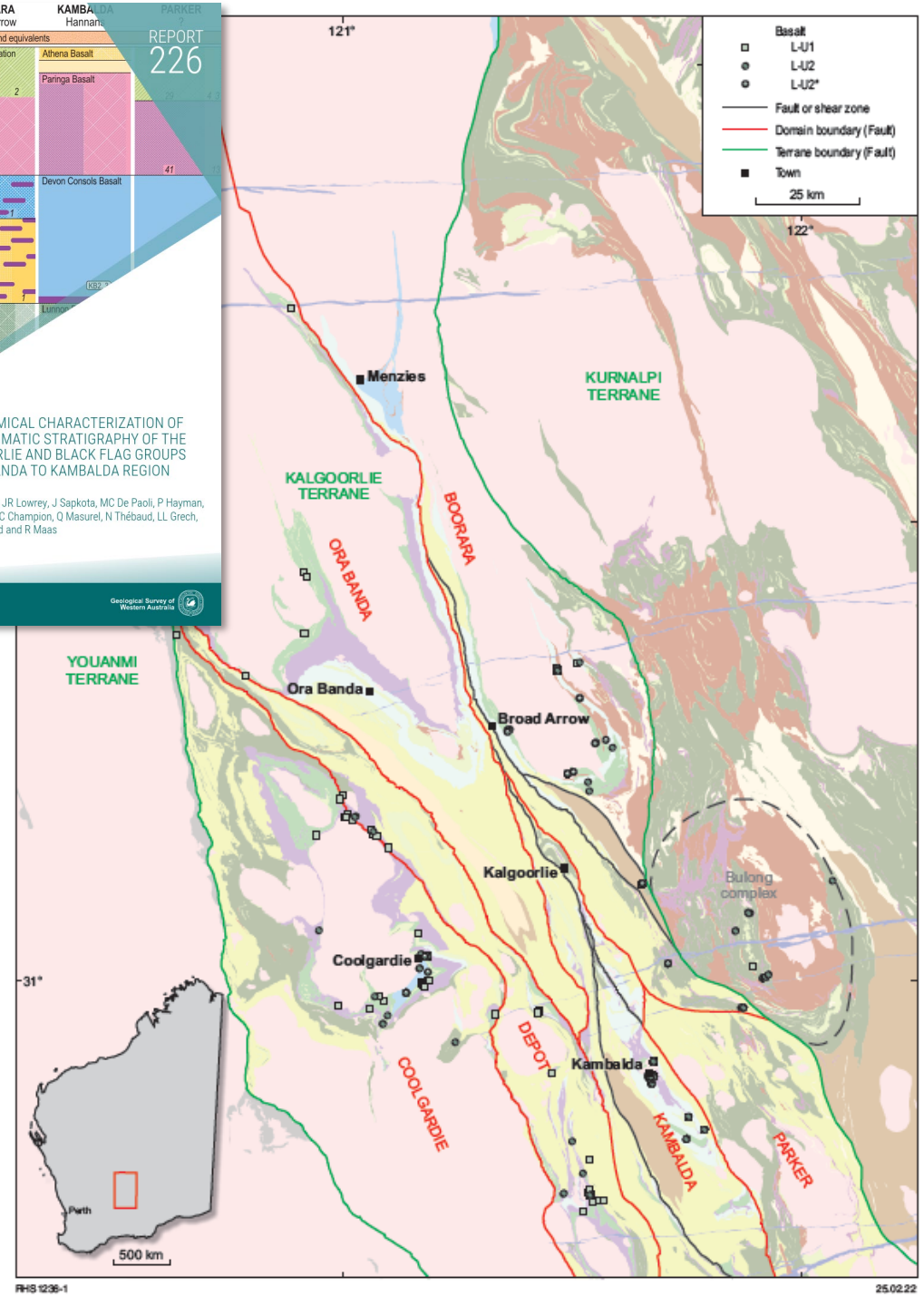
Magmatic stratigraphy

Geochemical ‘barcoding’ or chemostratigraphy incorporates:

- Extensive multi-element, high-quality geochemical data from mostly *mafic volcanic rocks (~2800 samples)
- Drill core logging and outcrop mapping
- Geochronology
- Isotope analysis
- Previous work

Enables stratigraphic testing of geochemical data

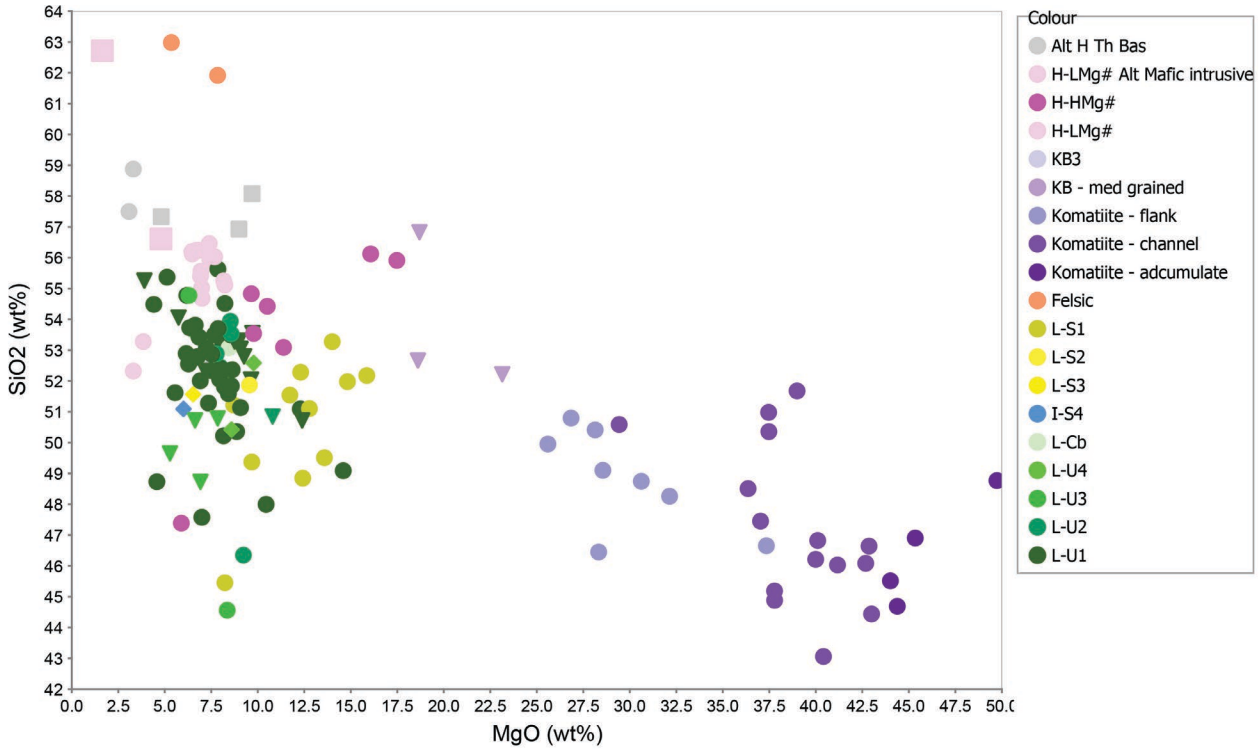




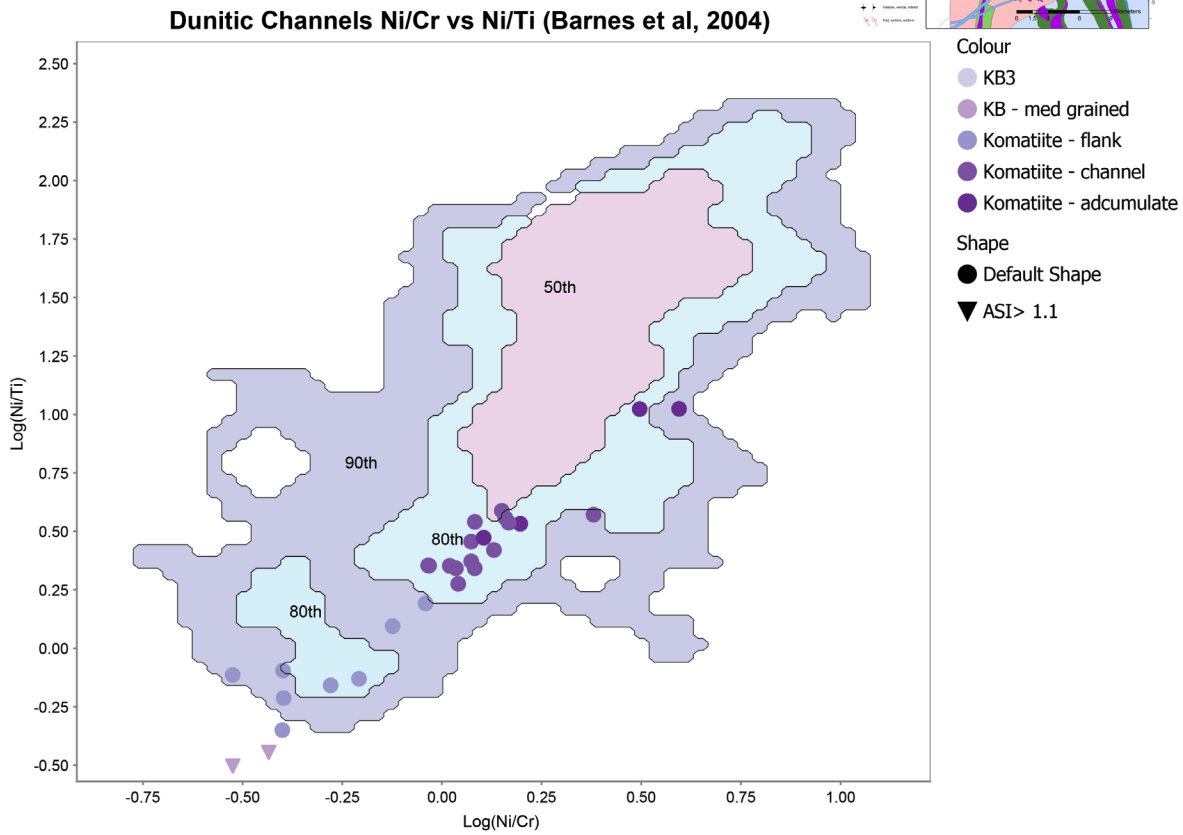
Smithies et al., (2022) GSWA Report

Differentiation of magmatic stratigraphy

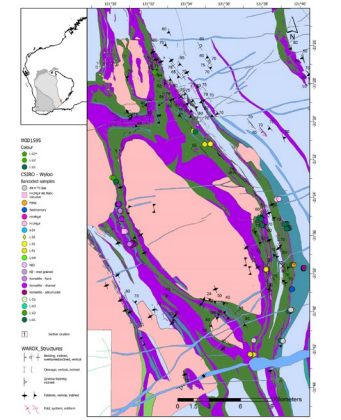
151 samples from around the dome



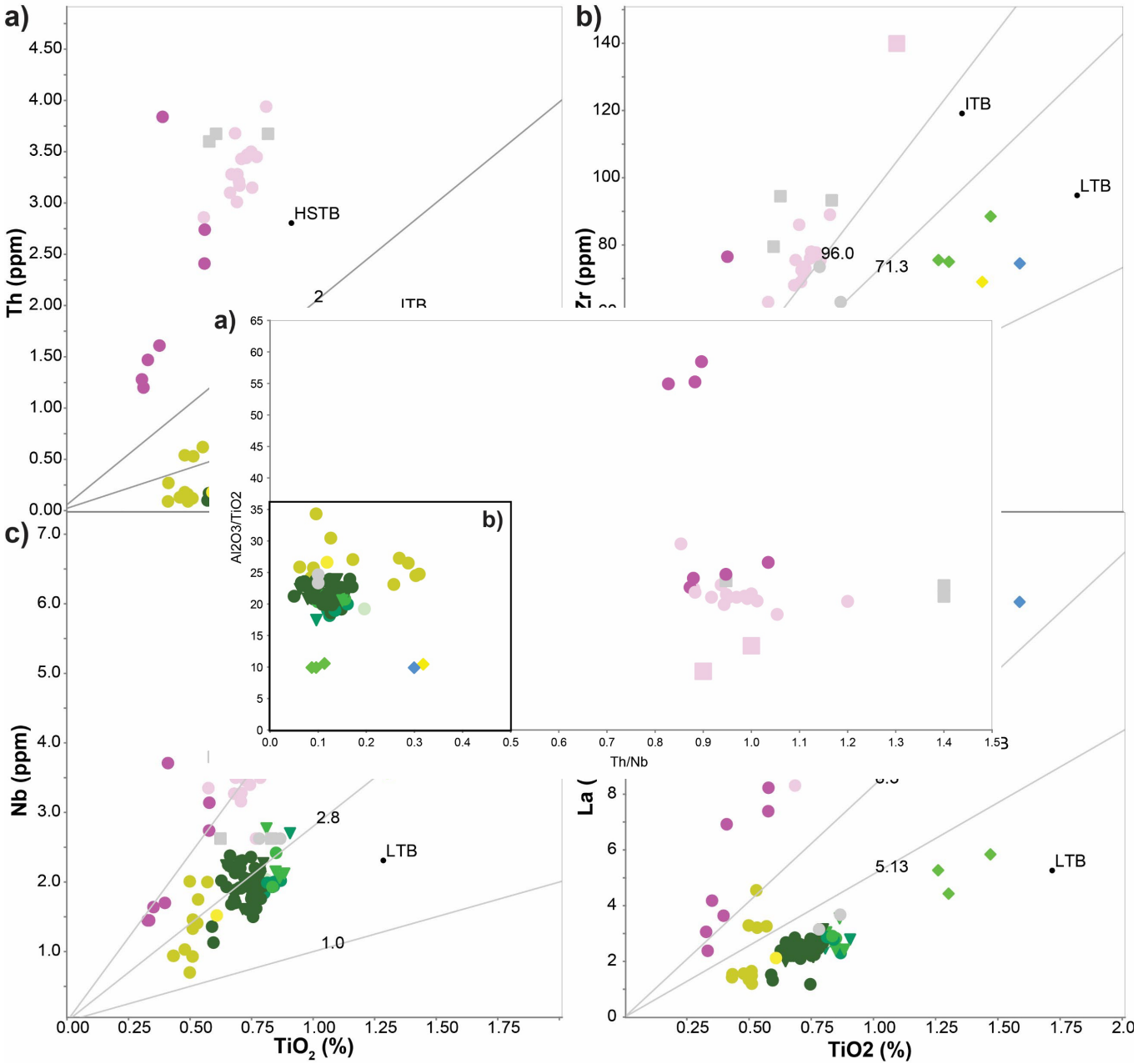
Separating mafic from ultramafic magmatic units

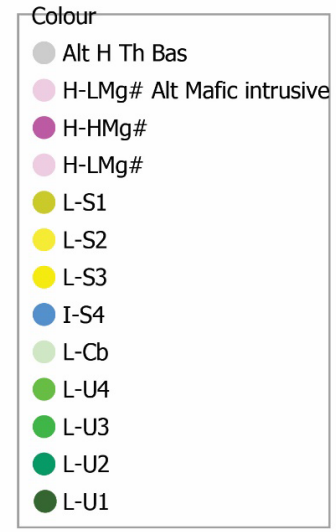


Separating komatiite channels vs flanks

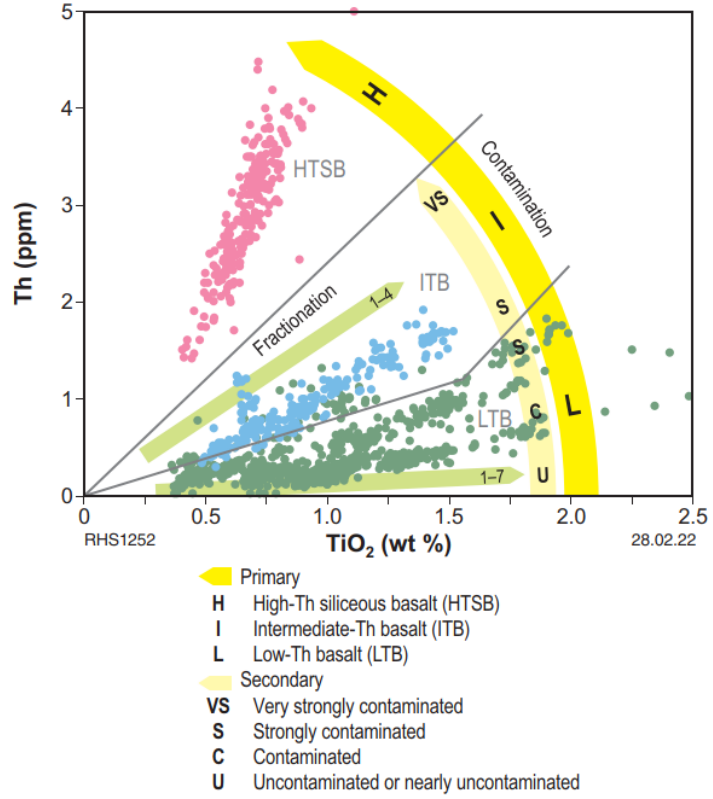


Samples classified as basalts only



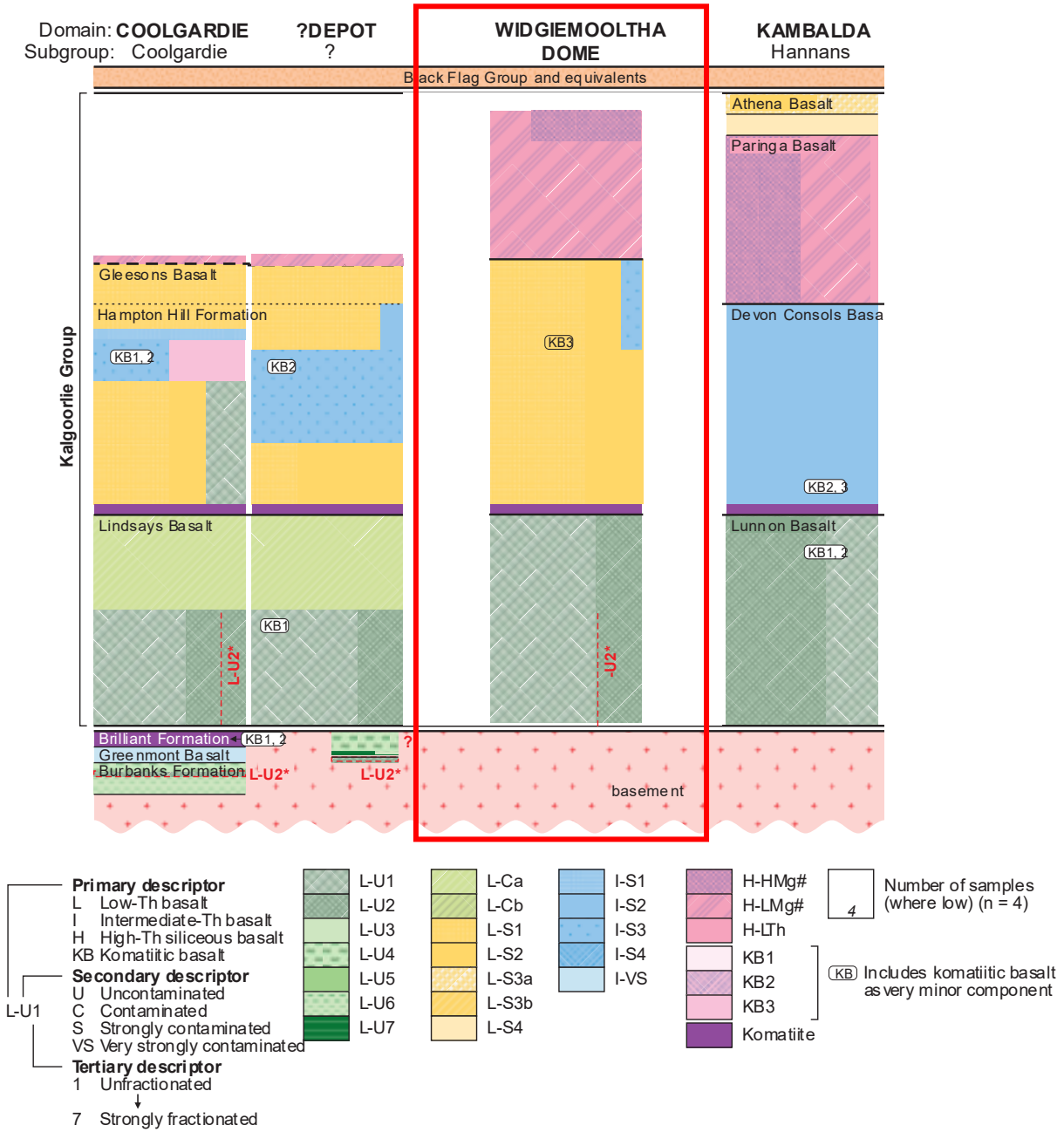


Smithies et al., (2022) GSWA Report

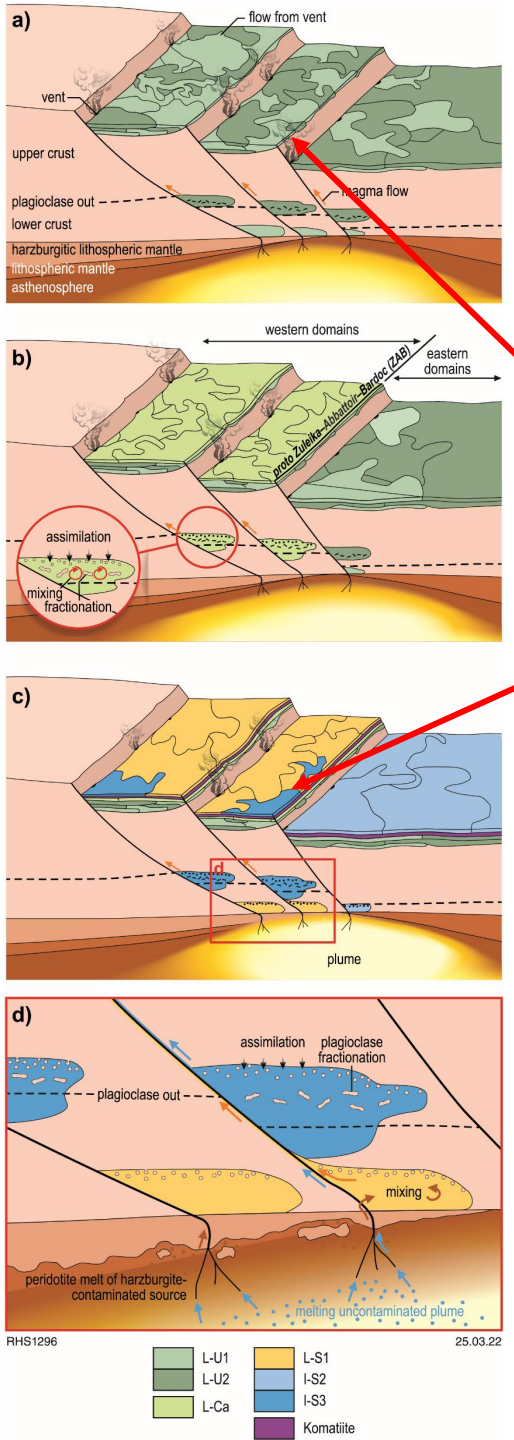


Comparison with Coolgardie and Kambalda Domains

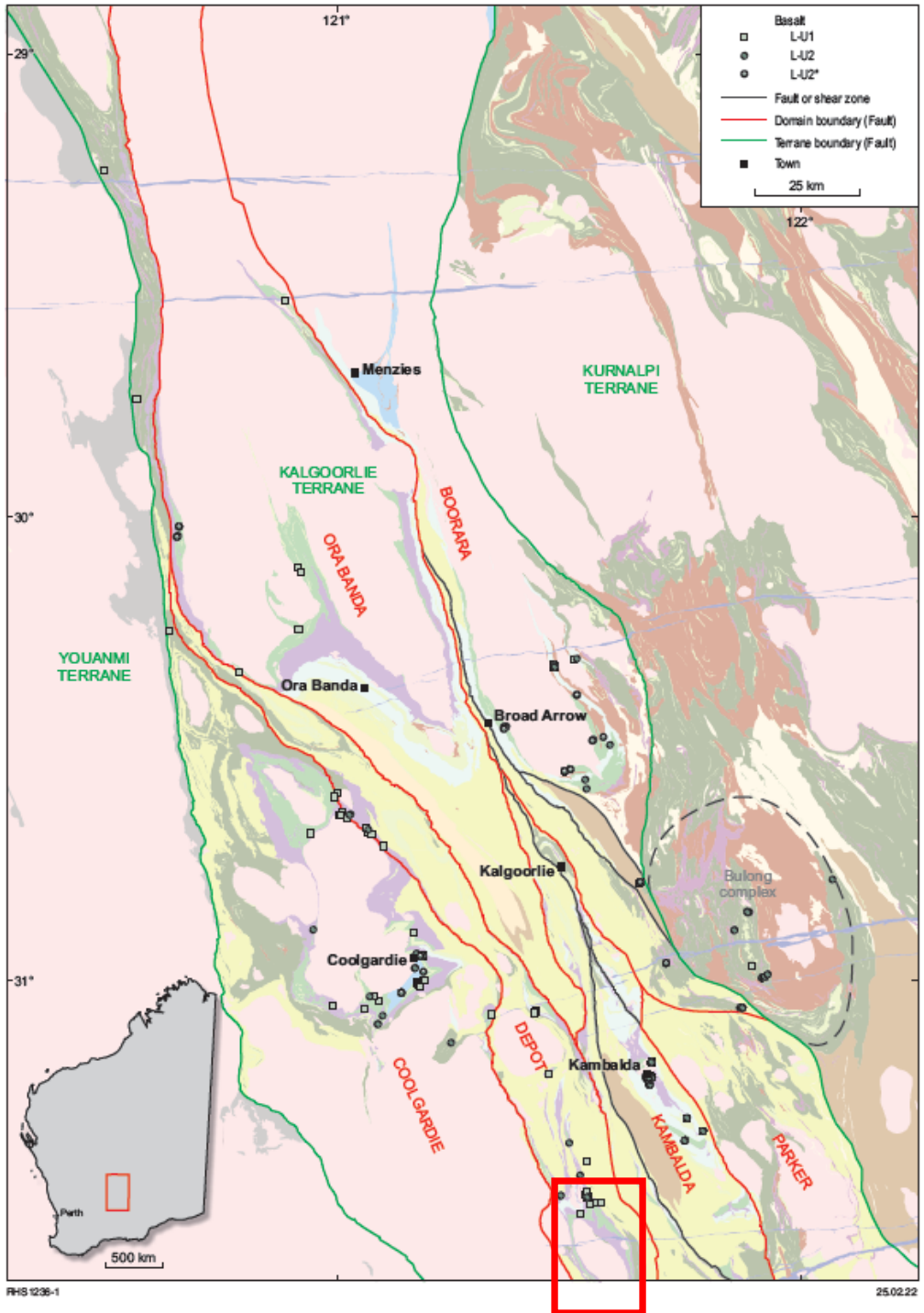
- Basal unit dominated by L-U1 and L-U2 (L-U3 only at Mariners with L-U1)
- More similar to Lunnon Basalt than Lindsays Basalt (exc. 1 x L-Cb)
- Abundant strongly contaminated L-S, limited I-S, therefore more similar to Hampton Hill Fm than Devon Consols Basalt
- Consistent upper stratigraphic position of HSTB in outer parts of dome (like Paringa Basalt)



Modified from Smithies et al., 2022



Widgiemooltha represents transitional zone



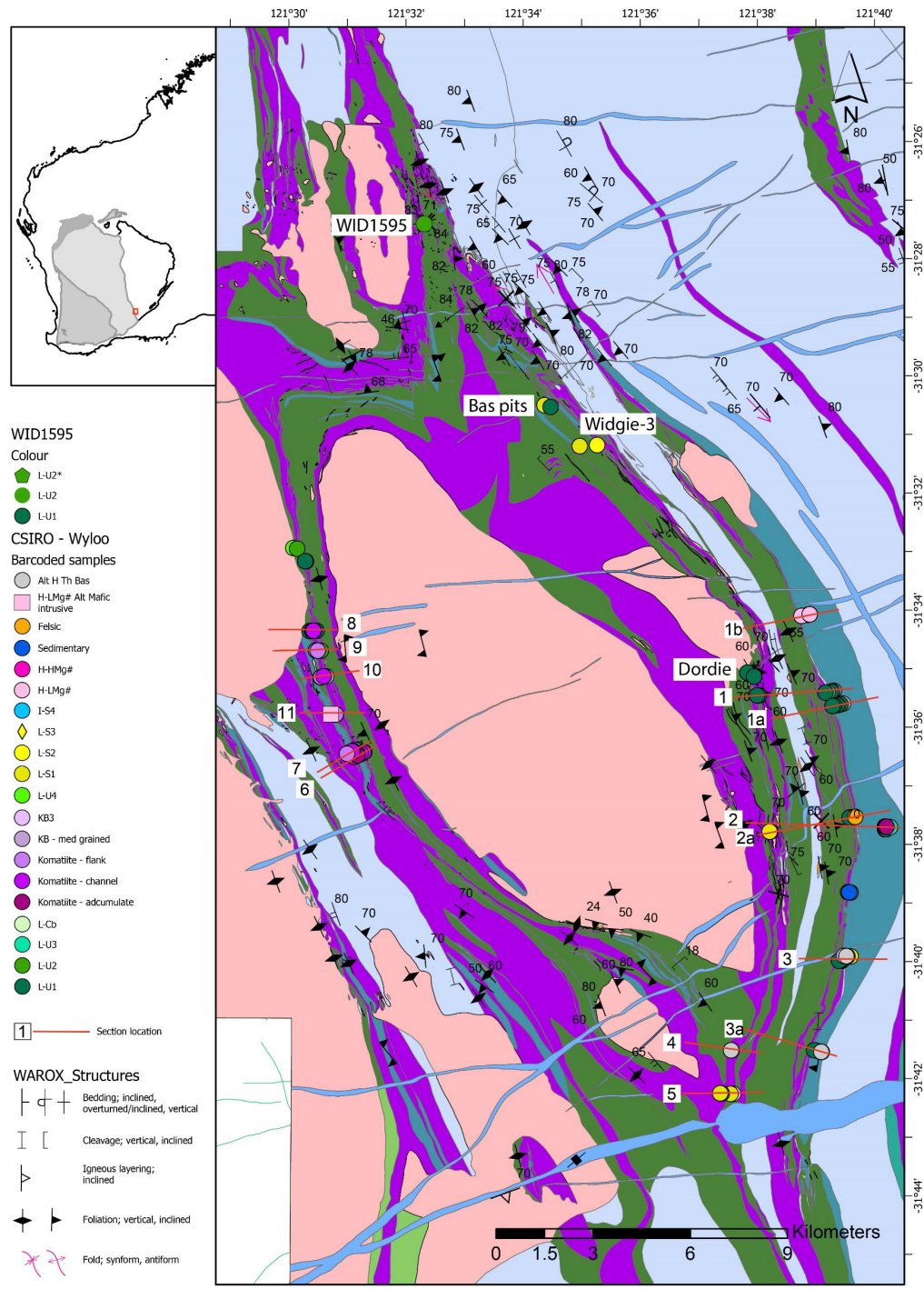
Smithies et al., (2022) GSWA Report

Structures and architecture of the Widgiemooltha Dome

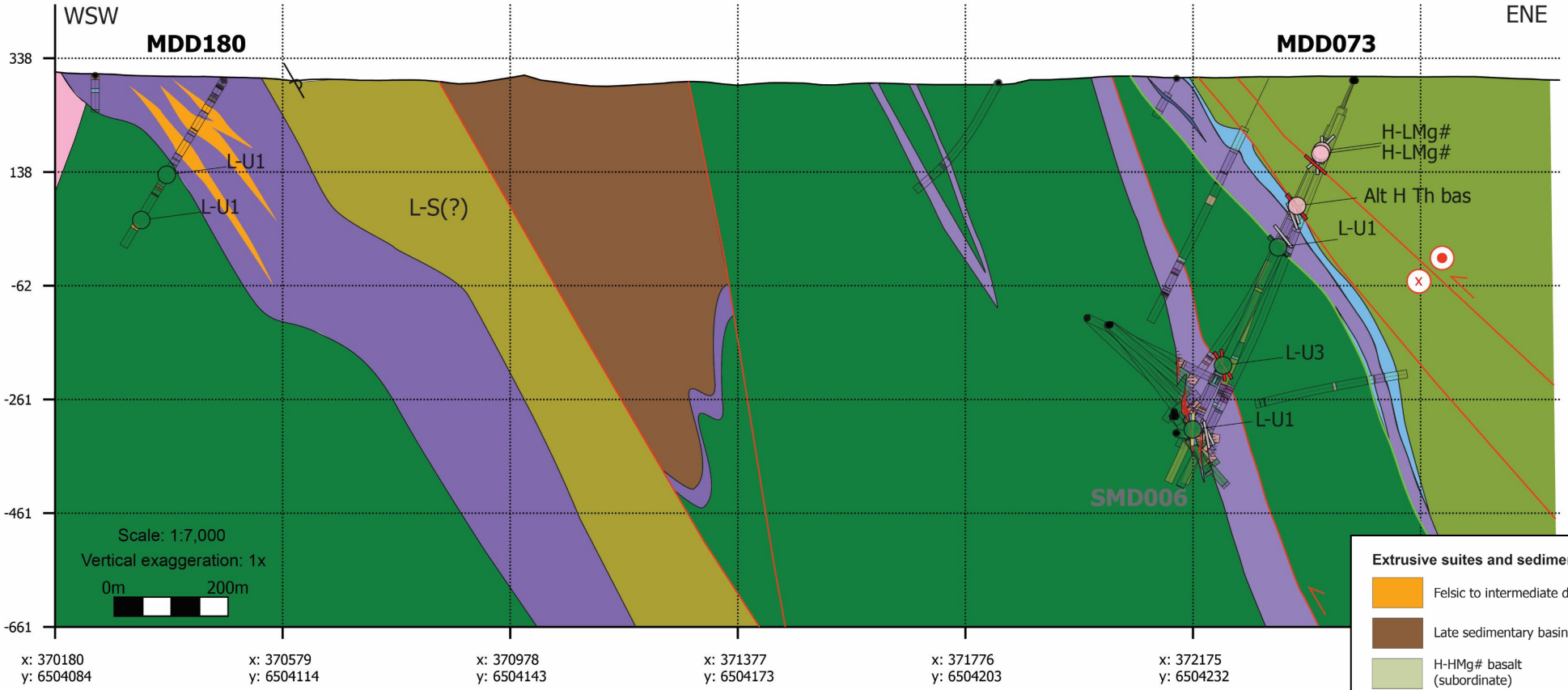
Structural logging and 15 cross-sections from key localities around the dome, including:

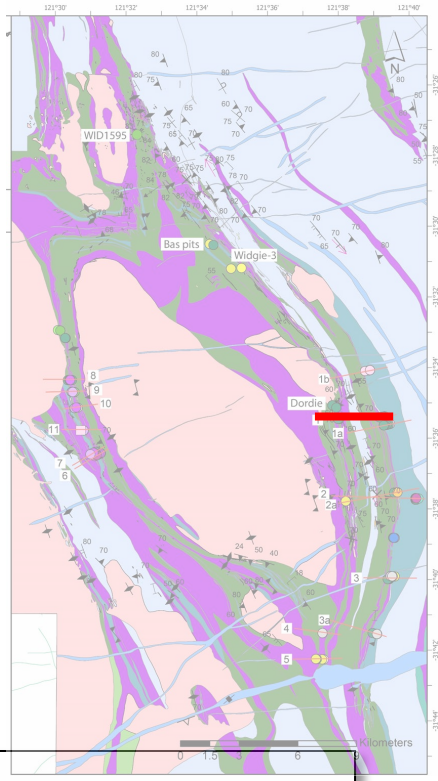
- Eastern limb
  - Miitel and Dordie
  - Mariners
  - Voyce and Redross
- Southern apex
  - Cassini
- Western Limb
  - Wannaway
  - Hartley

Used company map due to better correlation with geology intersected by drilling



Section 1 - Miitel Dordie - MDD073 MDD180





Location

A: 370179, 6504102
B: 372817, 6504299

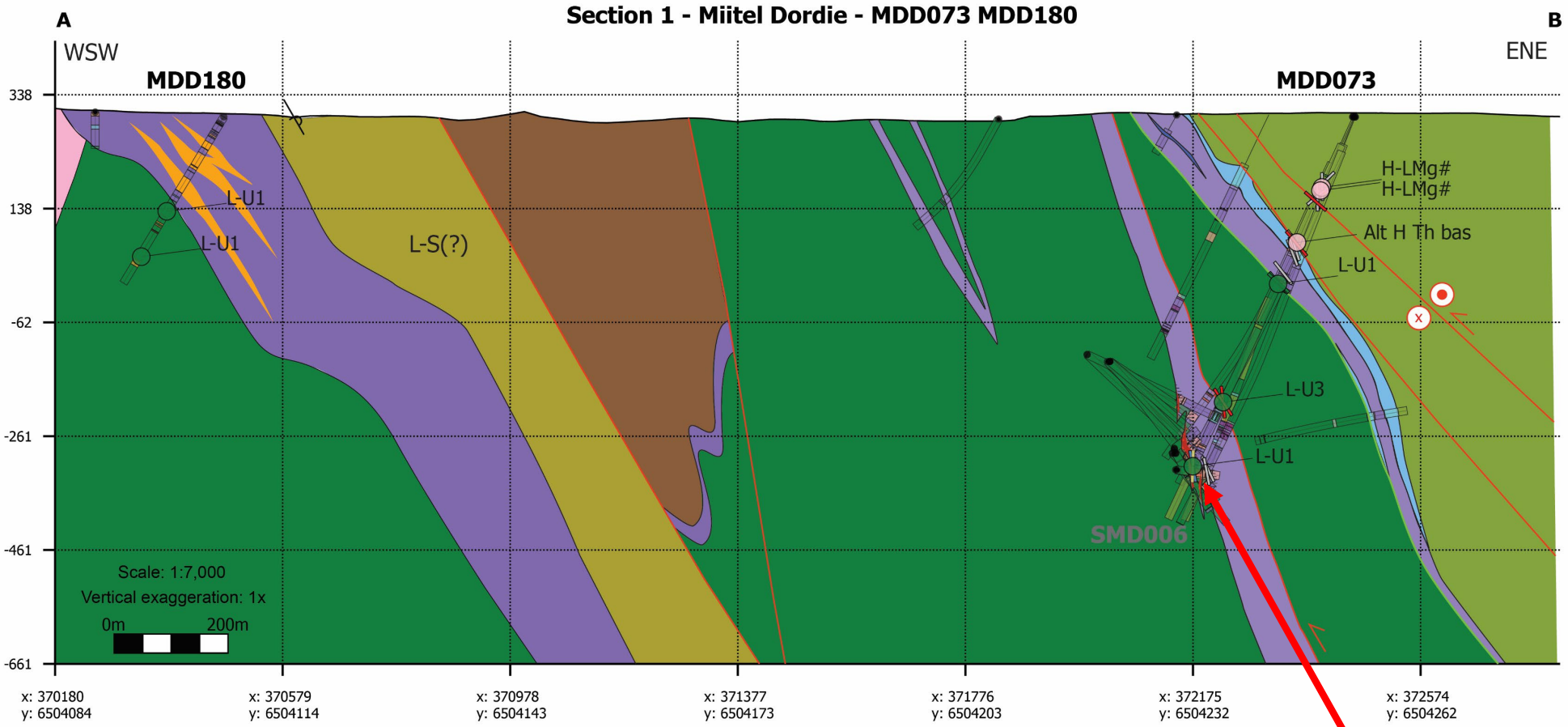
Extrusive suites and sedimentary rocks

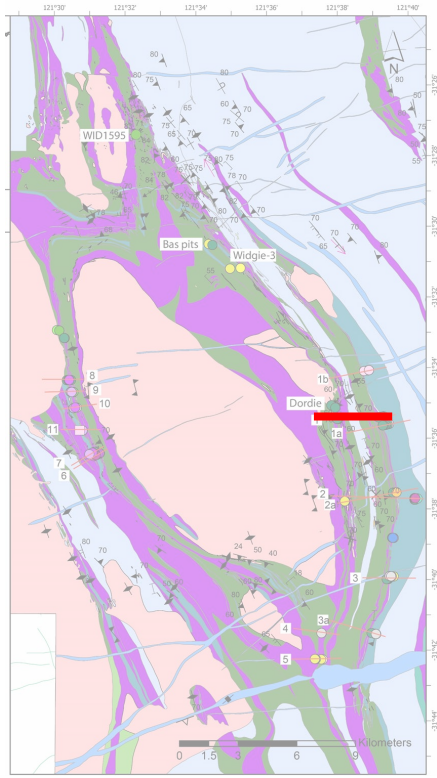
- Felsic to intermediate dykes
- Late sedimentary basin
- H-HMg# basalt (subordinate)
- H-LMg# basalt (dominant)
- L-U4 basalt (western Widgiemooltha only)
- L-S1/2 basalt
- Disseminated-blebby sulfides
- Matrix to massive sulfides
- Komatiite layer (with interflow sedimentary rocks)
- L-U1/2 basalt (Rare L-U3 closely assoc.)

- Strike slip fault (sinistral)
- Chl rich shear zone
- Shear zone
- Foliation trace
- Contact

Intrusive suites

- Dardie Monzogranite
- Larkinville Granodiorite

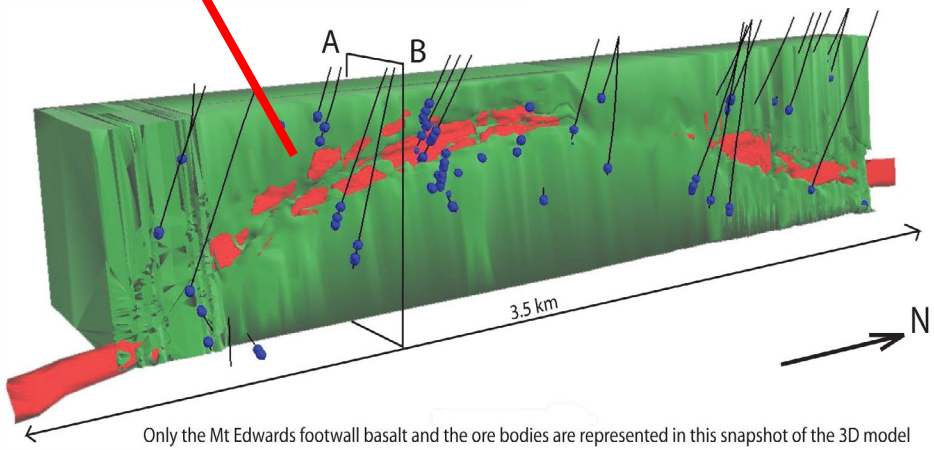




Location

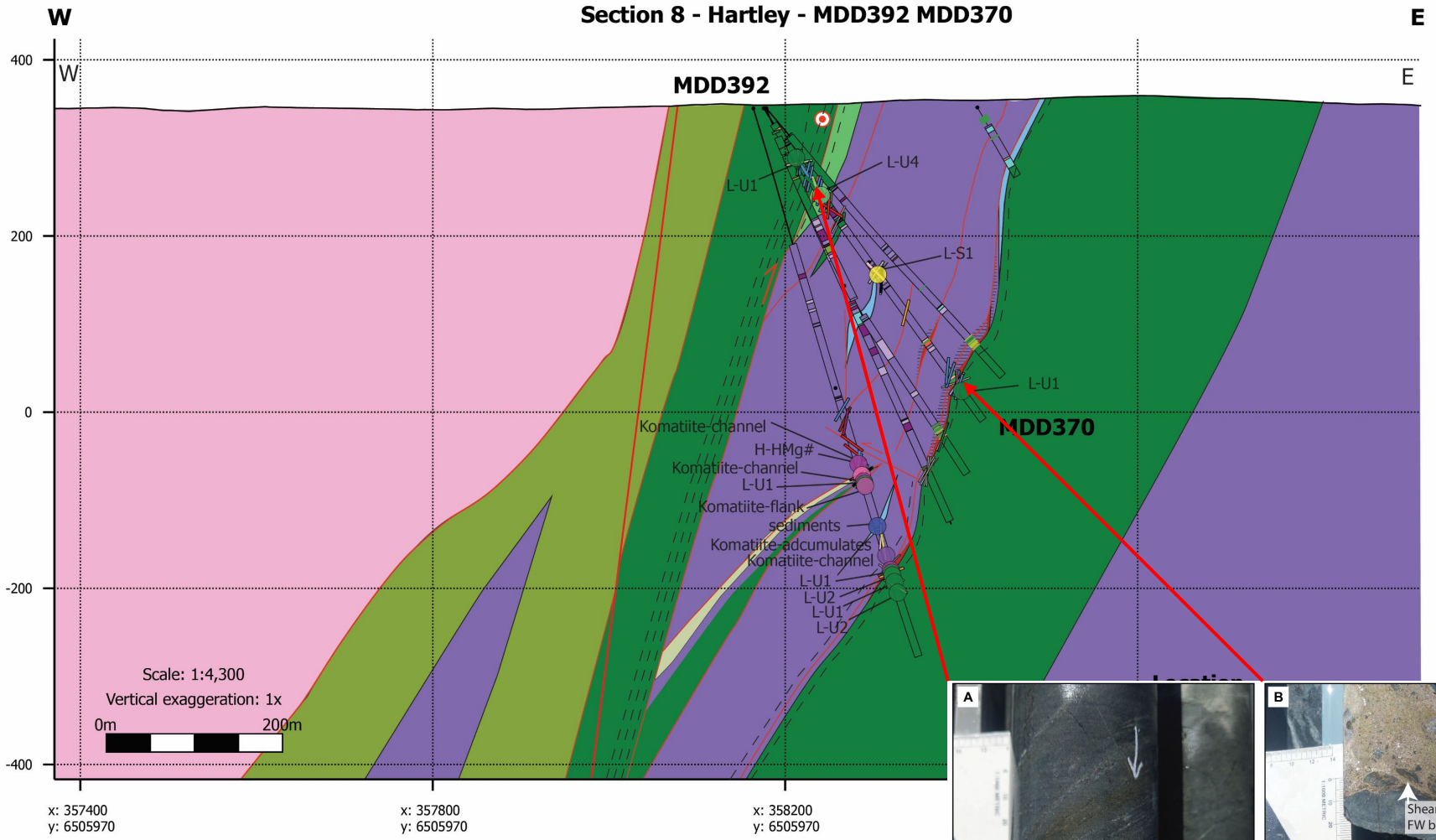
A: 370179, 6504102

B: 372817, 6504299

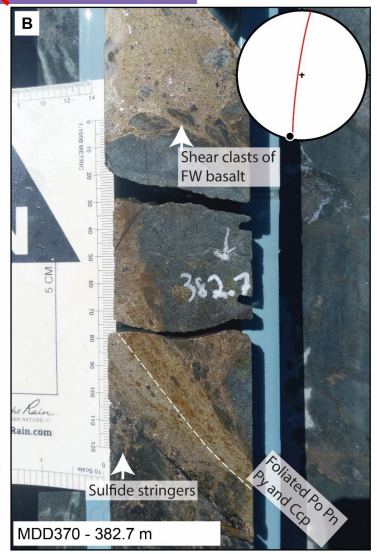


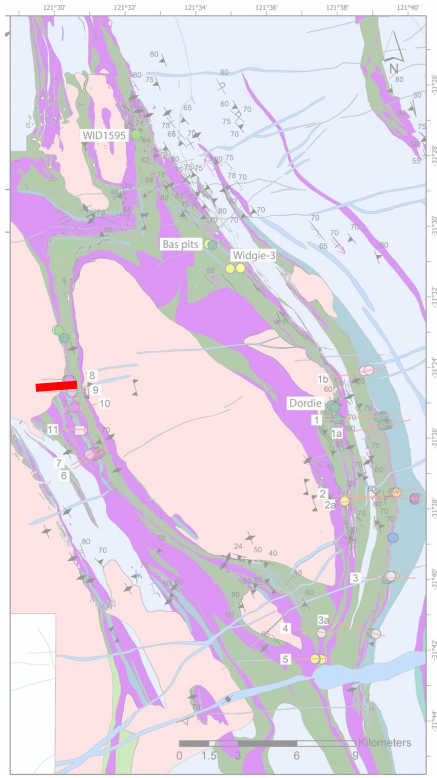
Le Vaillant et al., (2015) Econ. Geol.

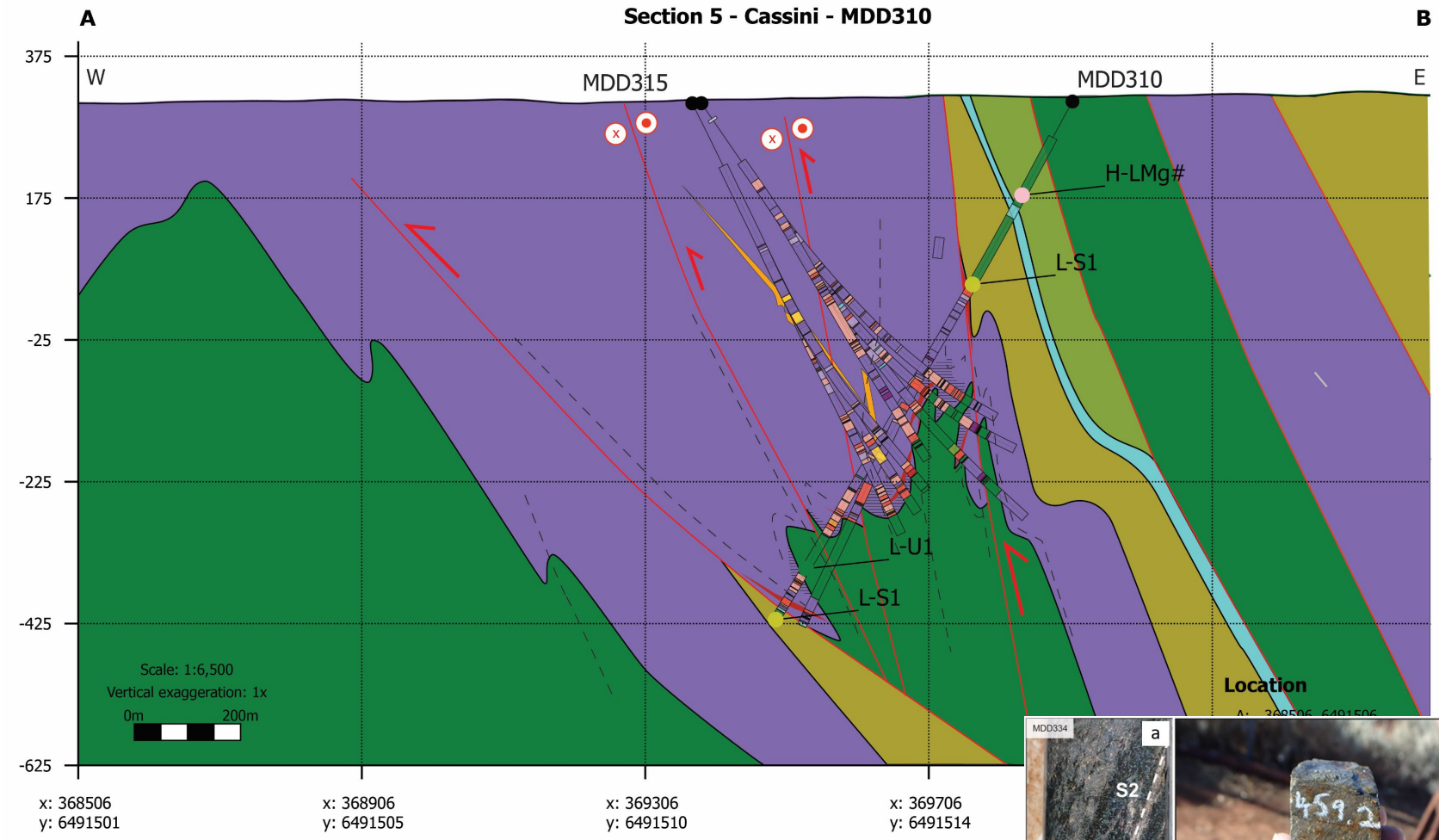
Only the Mt Edwards footwall basalt and the ore bodies are represented in this snapshot of the 3D model

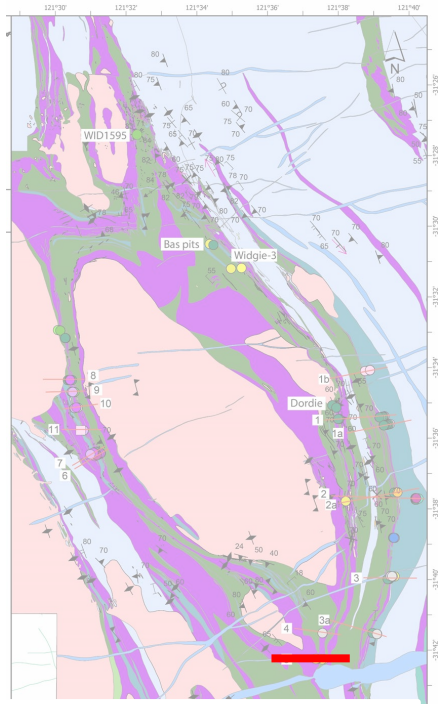

W
Section 8 - Hartley - MDD392 MDD370
E
400
200
0
-200
-400
W
MDD392
E
L-U1
L-U4
L-S1
L-U1
MDD370
Komatiite-channel
H-HMg#
Komatiite-channel
L-U1
Komatiite-flank-sediments
Komatiite-adcumulates
Komatiite-channel
L-U1
L-U2
L-U1
L-U2
Scale: 1:4,300
Vertical exaggeration: 1x
0m
200m
x: 357400
y: 6505970
x: 357800
y: 6505970
x: 358200
y: 6505970

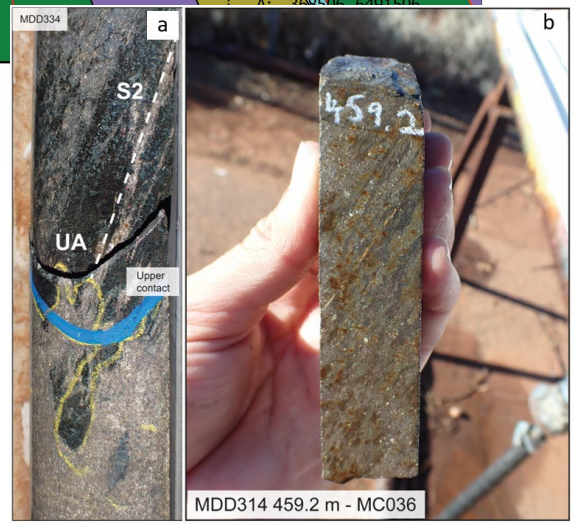

A
MDD370 - 87.6 m


B
Shear clasts of FW basalt
382.7
Sulfide stringers
Foliated Po Pn Py and Ccp
MDD370 - 382.7 m

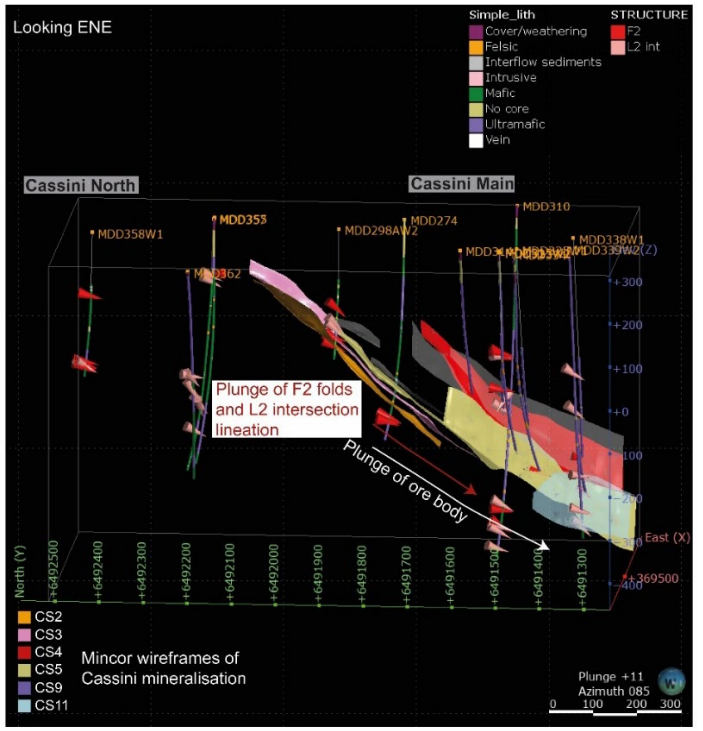

WID1595
Bas pits
Widgie-3
Dordie
Kilometers


A
Section 5 - Cassini - MDD310
B
375
175
-25
-225
-425
-625
W
MDD315
MDD310
E
H-LMg#
L-S1
L-U1
L-S1
Scale: 1:6,500
Vertical exaggeration: 1x
0m
200m
Location
x: 368506
y: 6491501
x: 368906
y: 6491505
x: 369306
y: 6491510
x: 369706
y: 6491514


WID1595
Bas pits
Widgie-3
Dordie

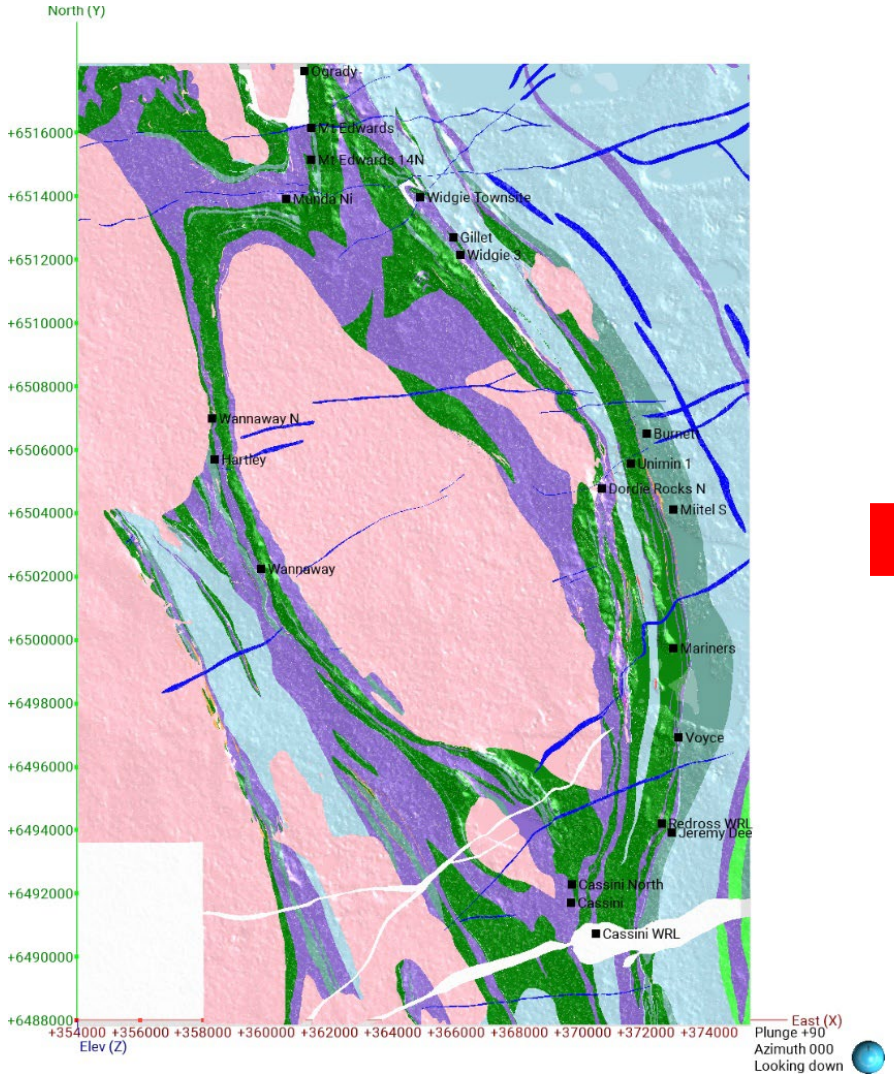

MDD334
a
S2
UA
Upper contact

b
459.2
MDD314 459.2 m - MC036

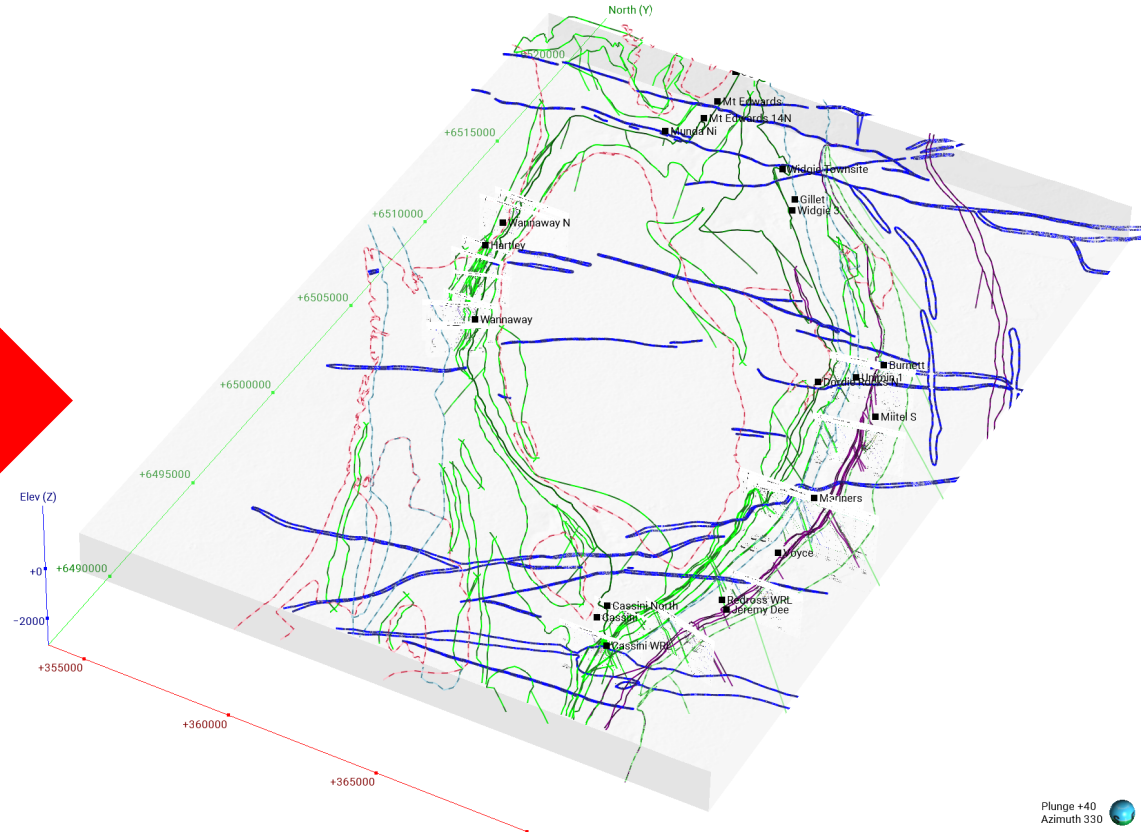

Looking ENE
Simple_lith
Cover/weathering
Felsic
Interflow sediments
Intrusive
Mafic
No core
Ultramafic
Vein
STRUCTURE
F2
L2 int
Cassini North
Cassini Main
MDD358W1
MDD353
MDD298AW2
MDD274
MDD310
MDD338W1
MDD362
Plunge of F2 folds and L2 intersection lineation
Plunge of ore body
North (Y)
East (X)
CS2
CS3
CS4
CS5
CS9
CS11
Mincor wireframes of Cassini mineralisation
Plunge +11
Azimuth 085

3D geological modelling

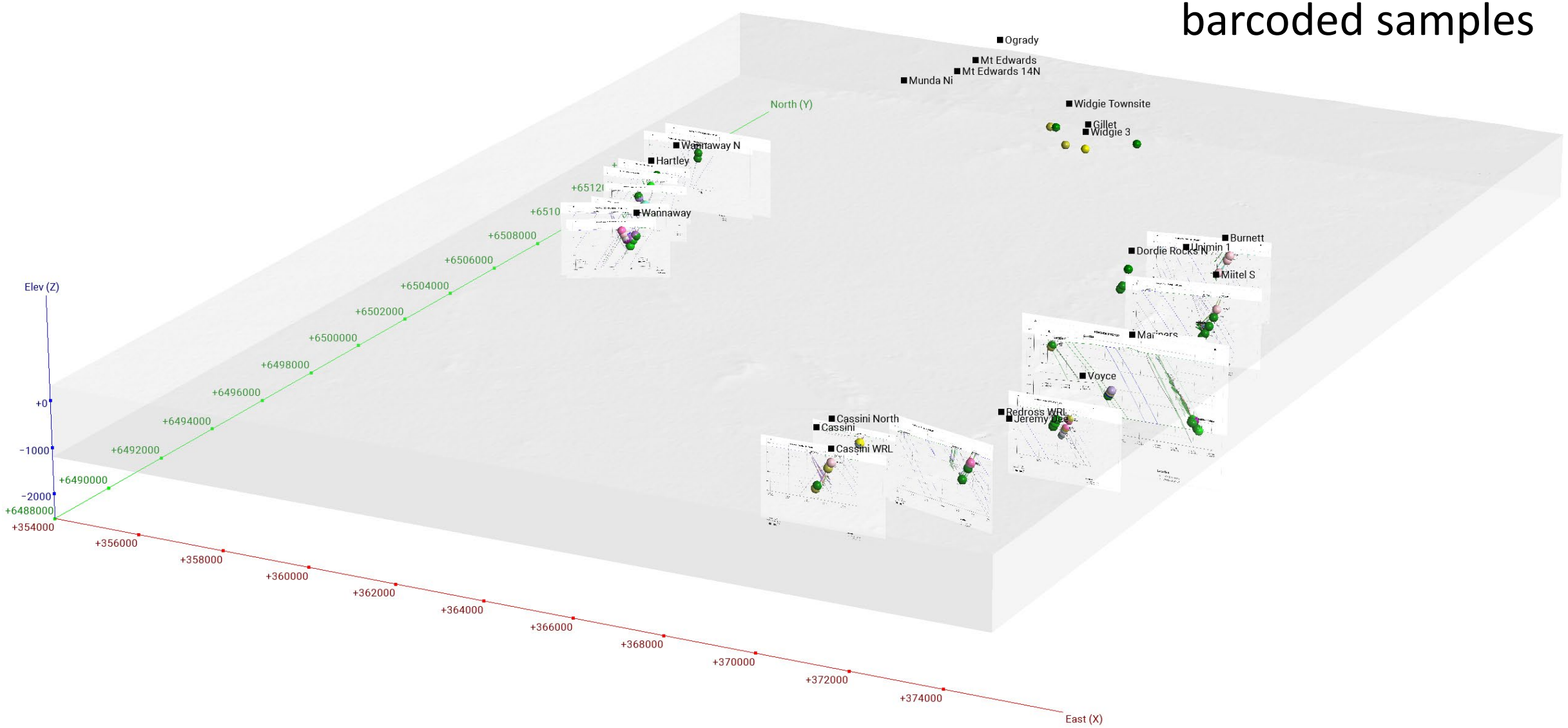
Company solid geology map



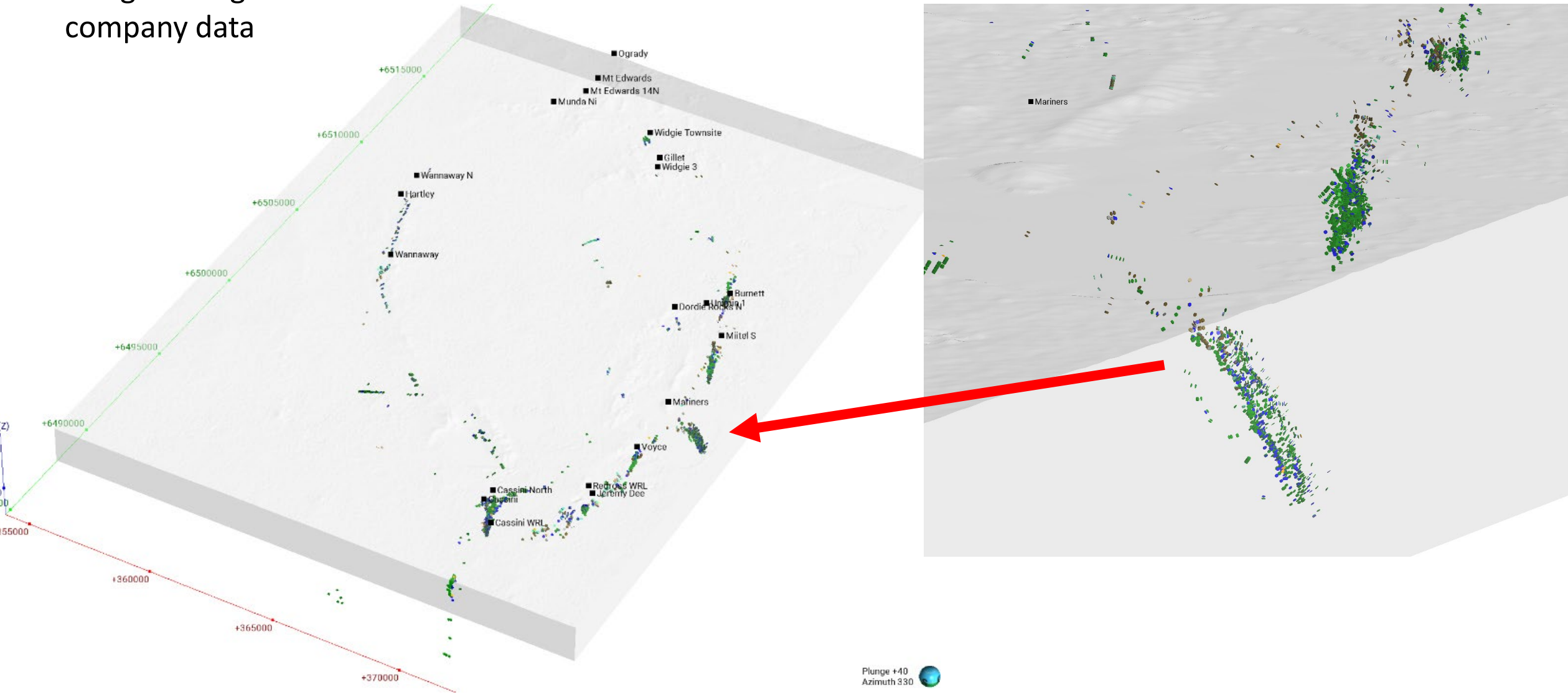
Digitised and simplified polylines outlining map units

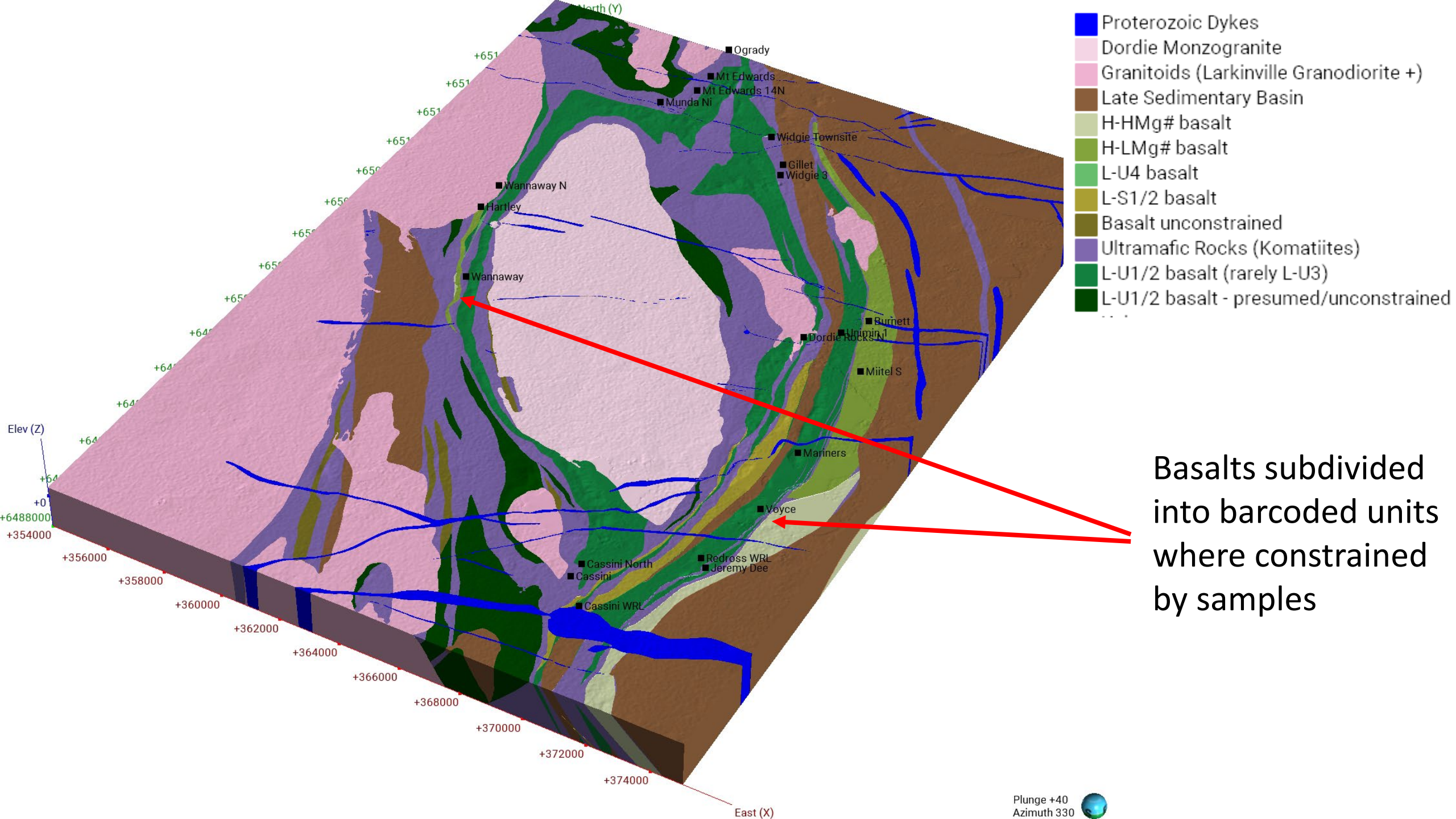


Cross-sections and barcoded samples

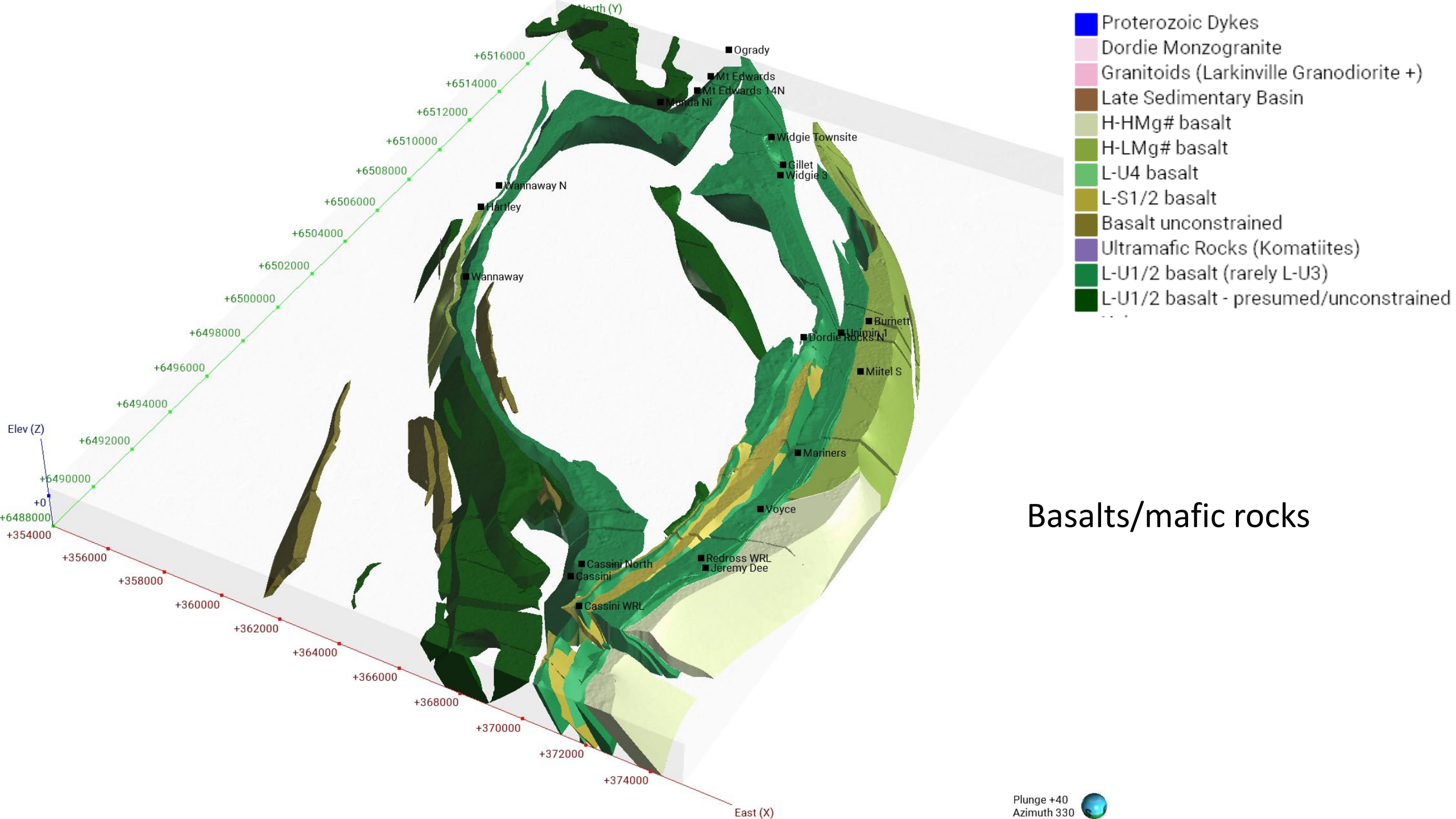


Litho-classification using existing company data

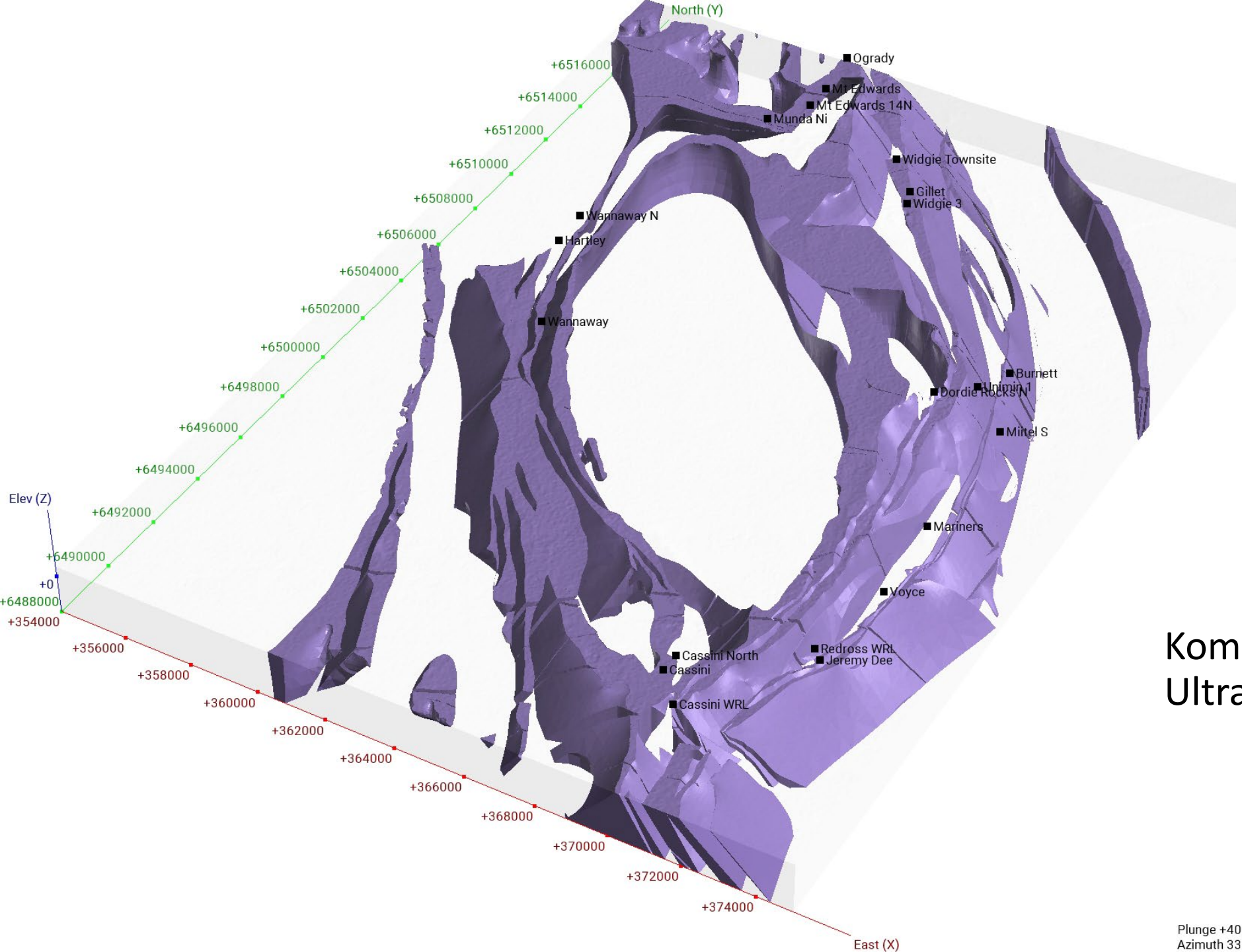




Basalts subdivided into barcoded units where constrained by samples



Basalts/mafic rocks

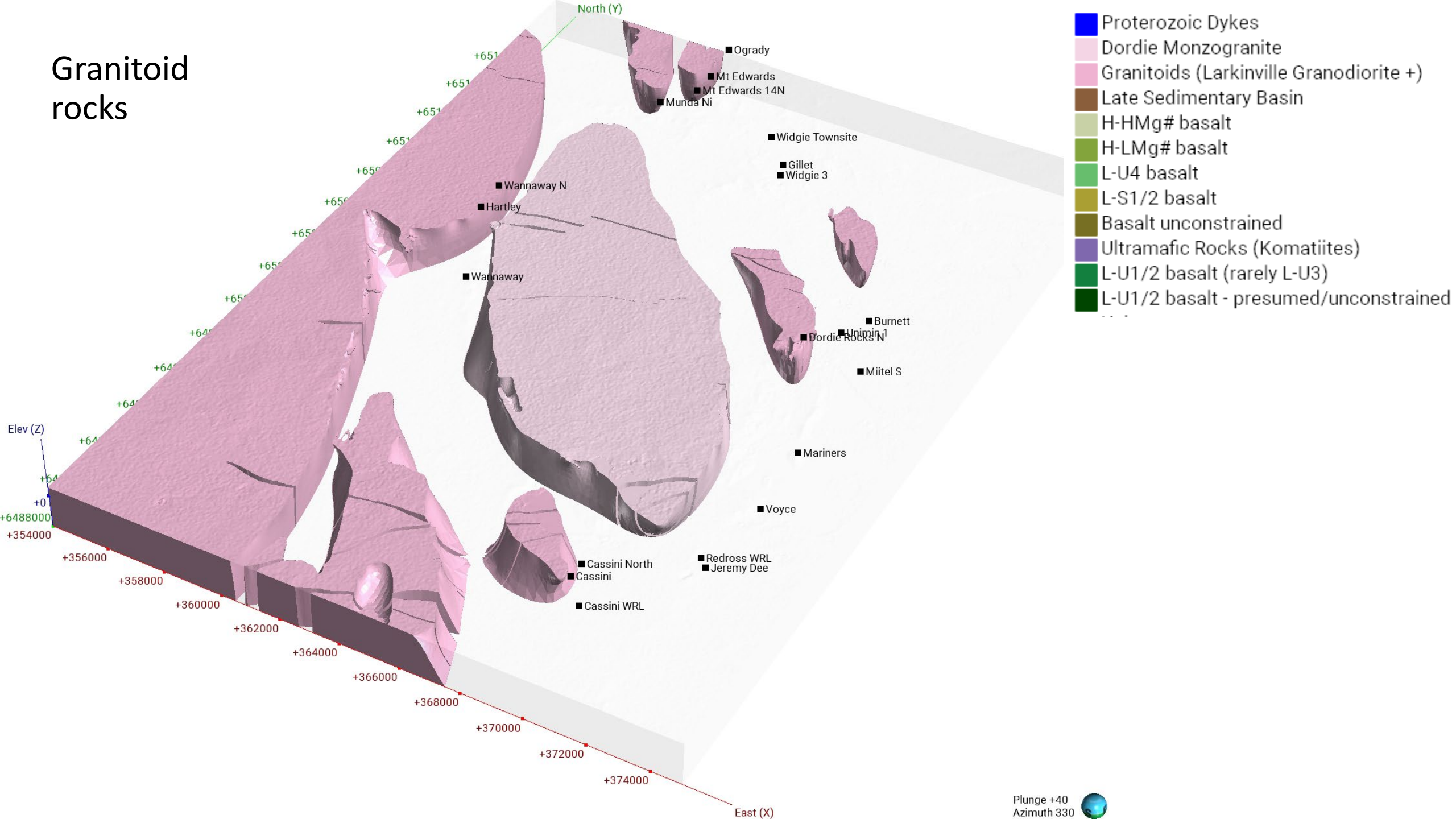


Proterozoic Dykes
Dordie Monzogranite
Granitoids (Larkinville Granodiorite +)
Late Sedimentary Basin
H-HMg# basalt
H-LMg# basalt
L-U4 basalt
L-S1/2 basalt
Basalt unconstrained
Ultramafic Rocks (Komatiites)
L-U1/2 basalt (rarely L-U3)
L-U1/2 basalt - presumed/unconstrained

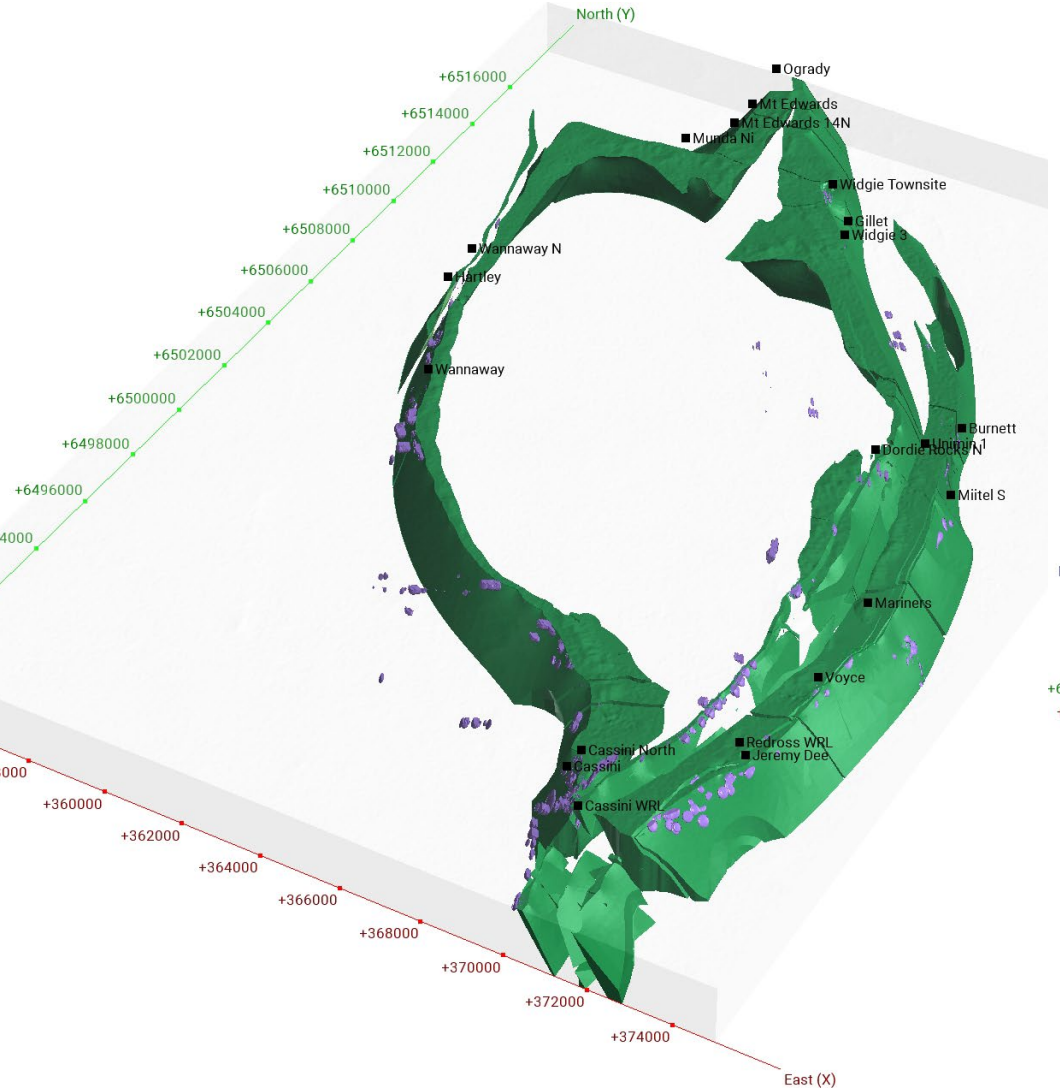
Komatiites/ Ultramafic rocks

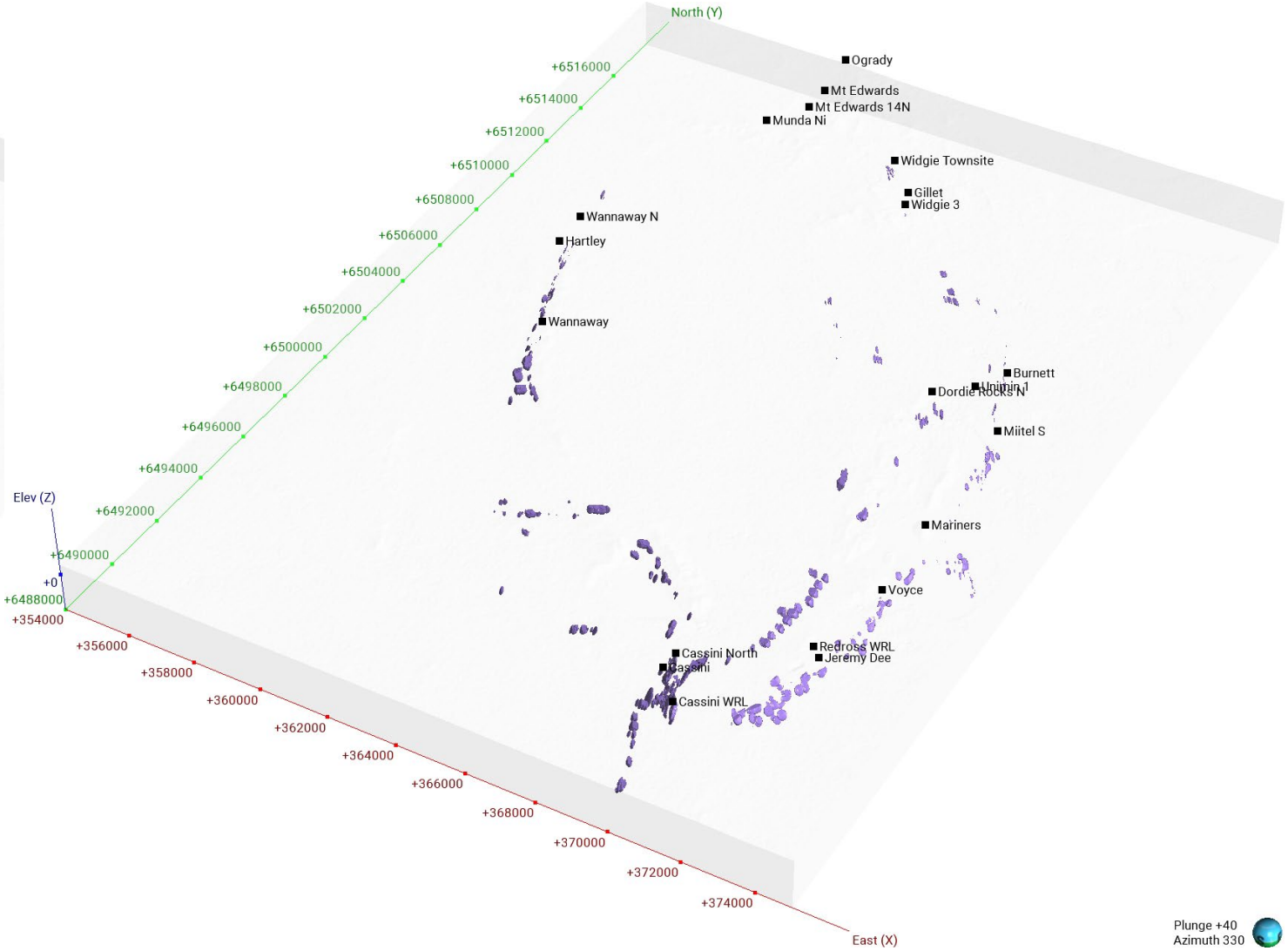
Plunge +40
Azimuth 330

Granitoid rocks



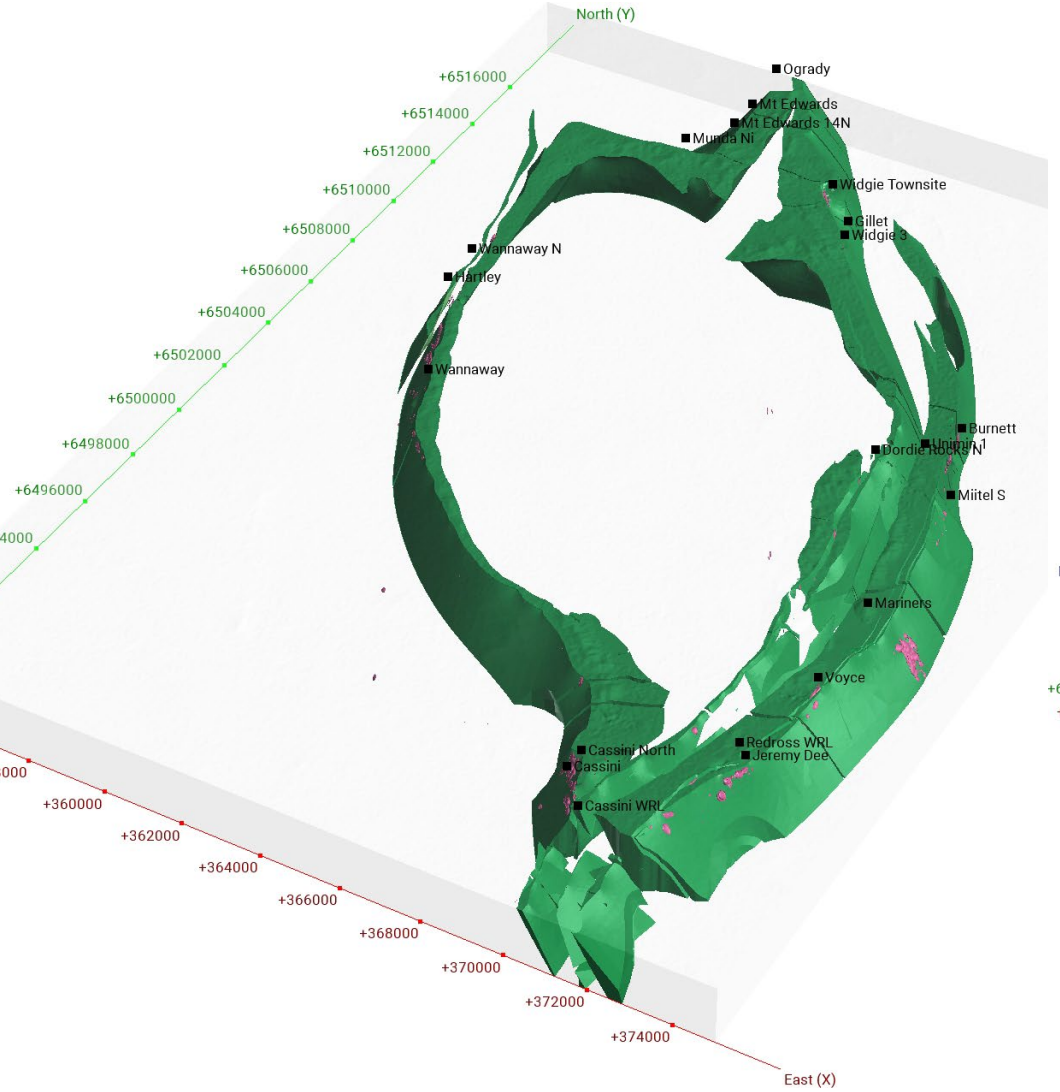
Komatiite – flows (and adjacent basalts)

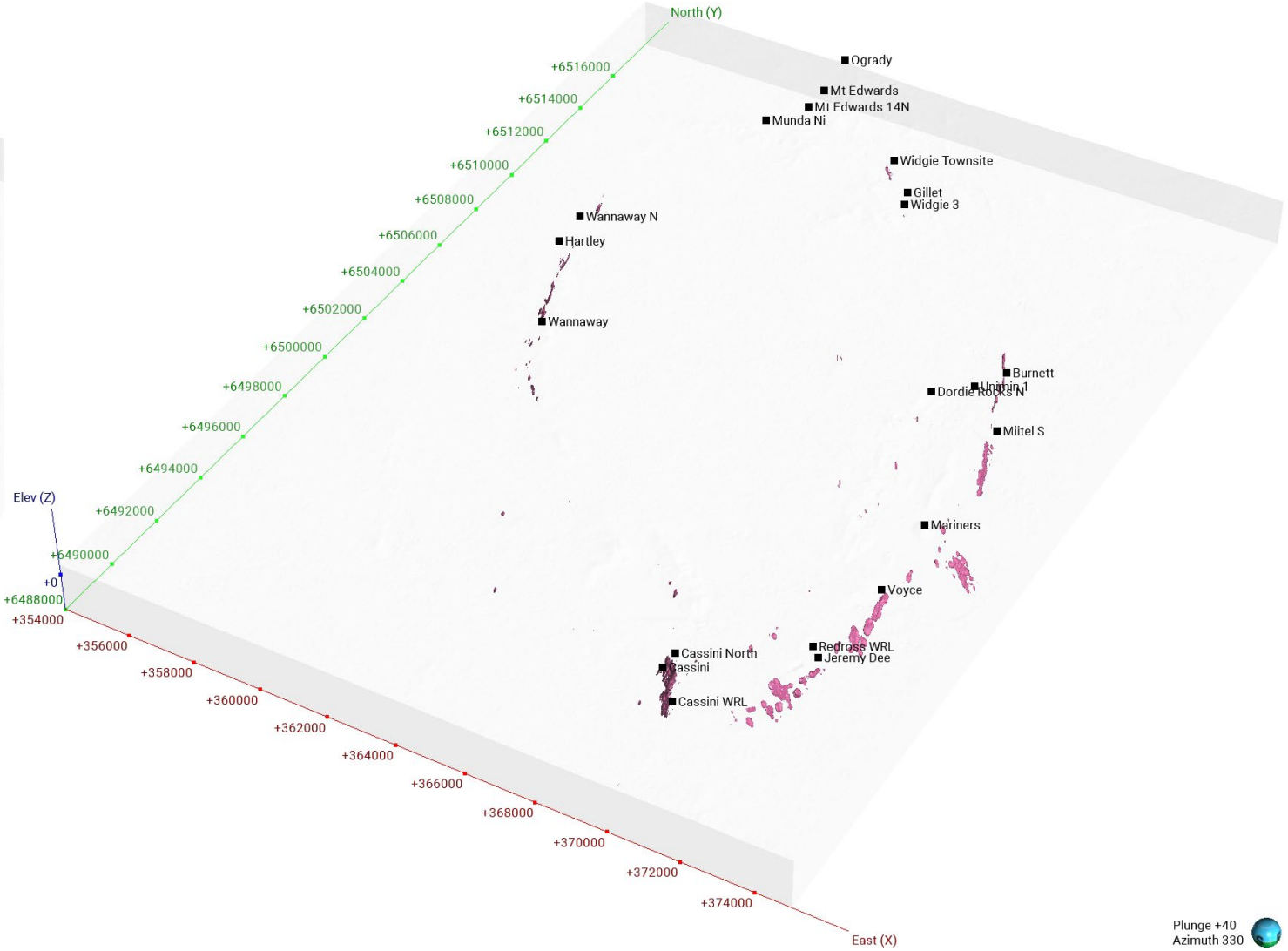




Plunge +40
Azimuth 330

Komatiite – cumulates (and adjacent basalts)





Plunge +40
Azimuth 330

Key Outcomes

- “Barcoded” samples can be connected to mapping and drillhole logging
- Thick panel of L-S1/2 (Low Thorium, strongly contaminated, fractionated) basalt on east side of dome can be identified
- Captures macro-geometries of antiform-synform pairs with intense parasitic folding in east and strike slip deformation in west
- Inconsistent structural settings of mineralisation – preservation of channels in the east, stronger mechanical remobilisation towards west and south
- Lithoclasses from assays difficult to extrapolate away from drilling; requires further basalt sampling

Limitations of applied 3D geological modelling

- 3D geological model DOESN'T include faults (!!!)
  - Lack of marker horizons, limited constraints on fault geometry and amount of displacement
  - Inclusion of faults in Leapfrog generates fault blocks which disturbs stratigraphy and major architecture – creates artifacts
  - Time constraints

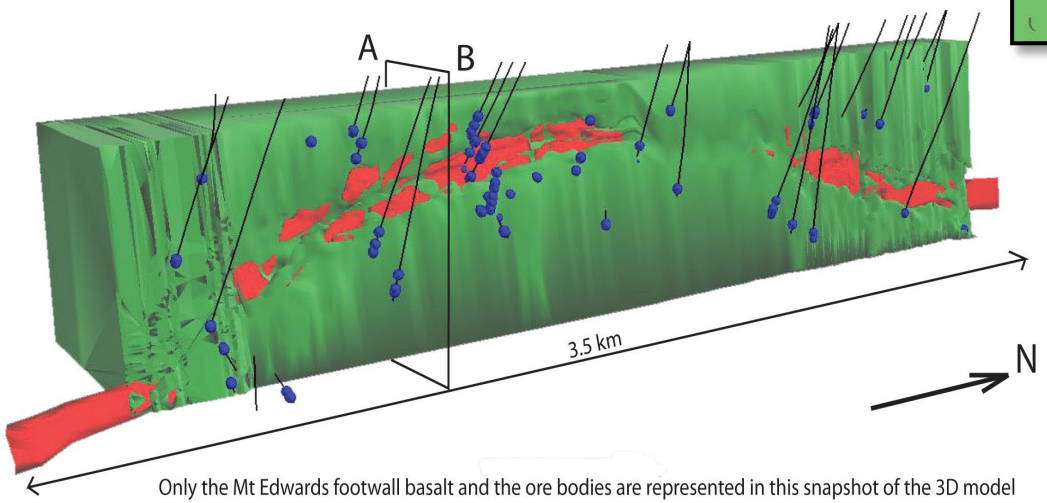
- Not necessarily reproducible - includes geologist biases
- Multiple versions of solid geological maps of area
  - Based on different interpretations of magnetic data
- Lacks scalability and incorporation of principles of structural geology
- Doesn't allow for uncertainty quantification

Implications for mineralisation

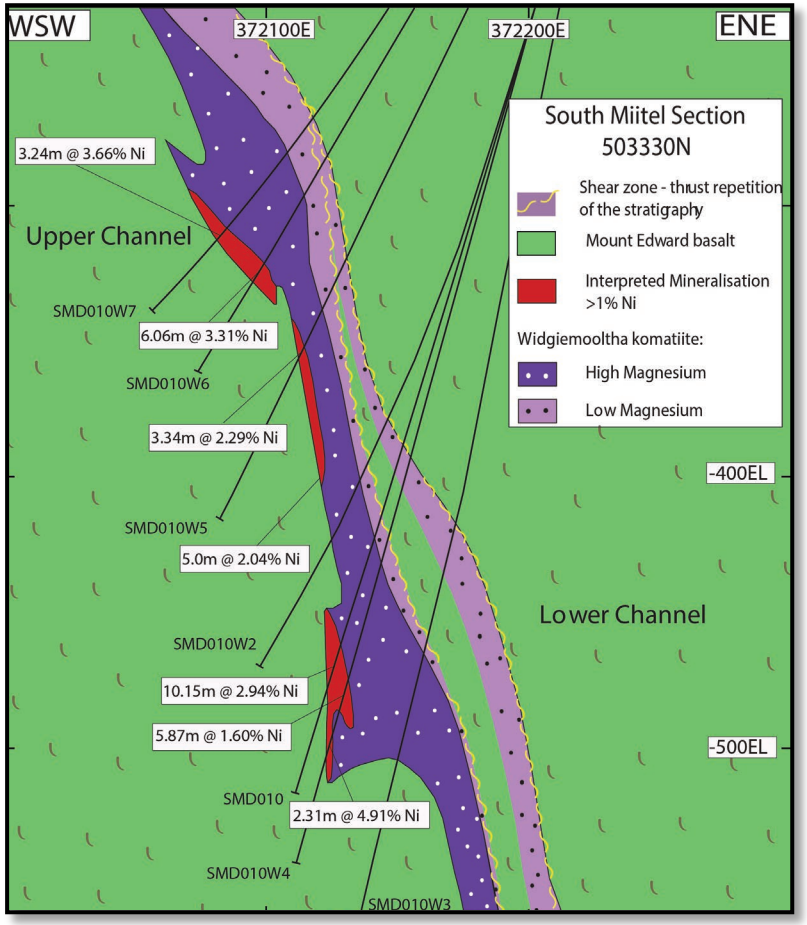
1) Structural repetition of komatiite over footwall LTB prior to folding – influencing understanding of prospectivity of komatiite occurrences
2) Diverse preservation and remobilisation around the dome

Miitel

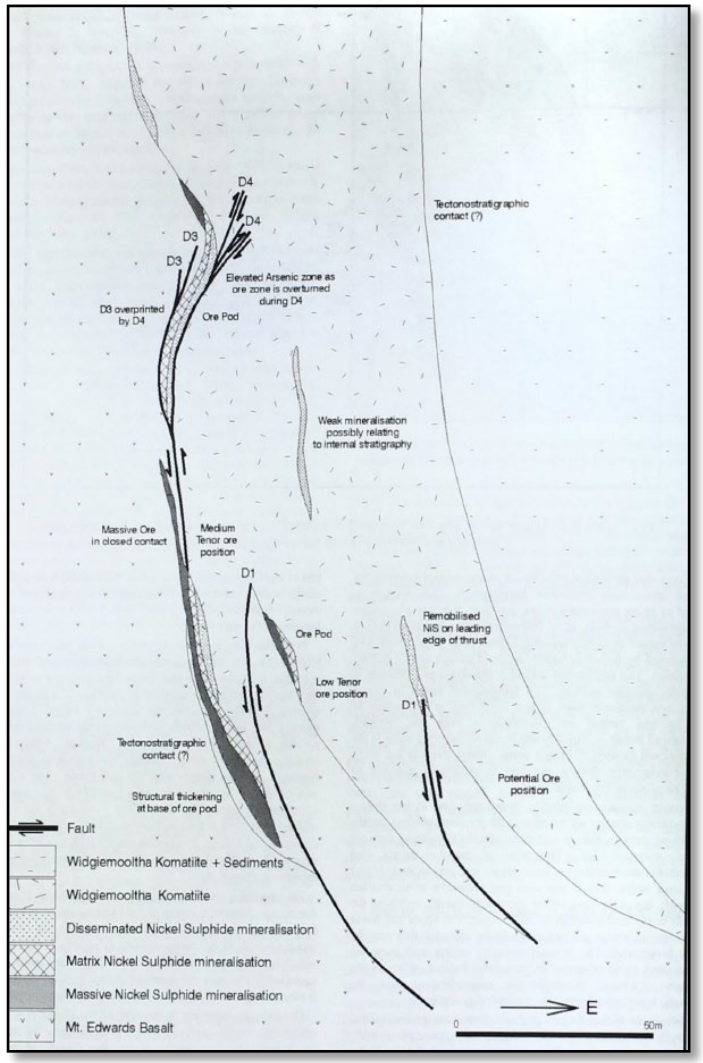
- Preservation of channel morphologies due to strain portioning into komatiite hanging wall contact
- Minor overprinting by high angle fault system



Only the Mt Edwards footwall basalt and the ore bodies are represented in this snapshot of the 3D model



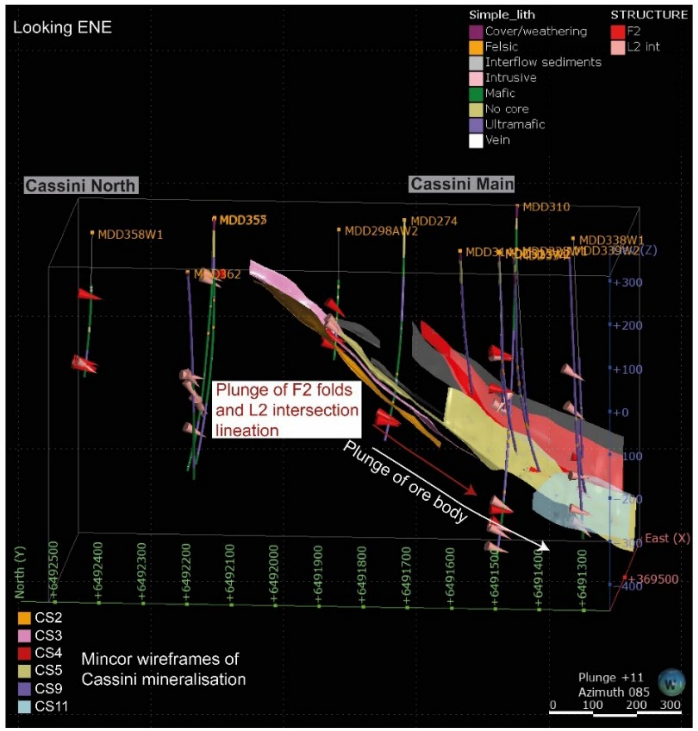
Le Vaillant et al., (2015) Econ. Geol.

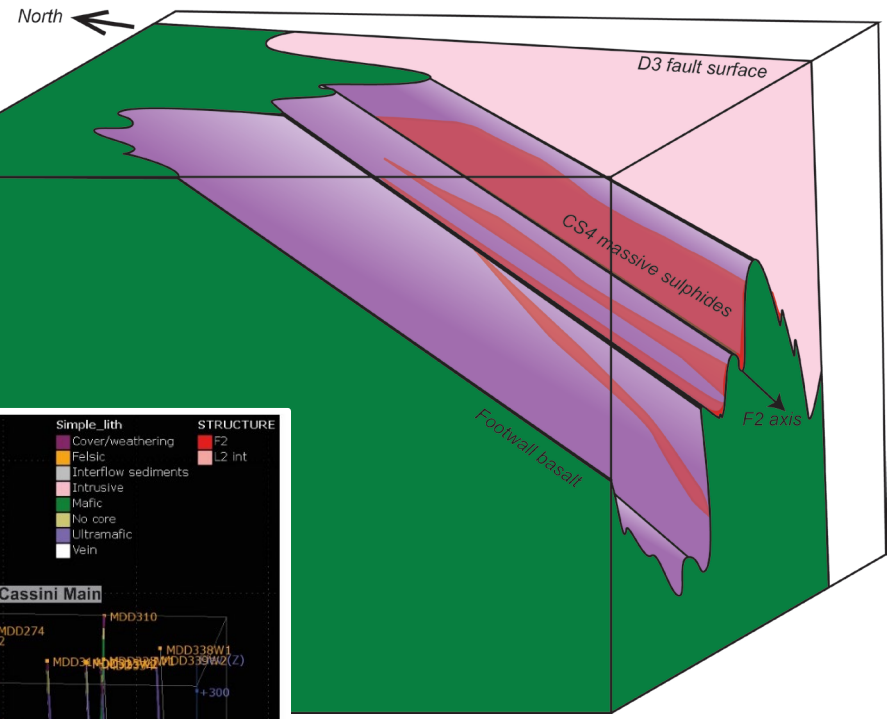


Cairns et al., (2003) Int. Mining Conference

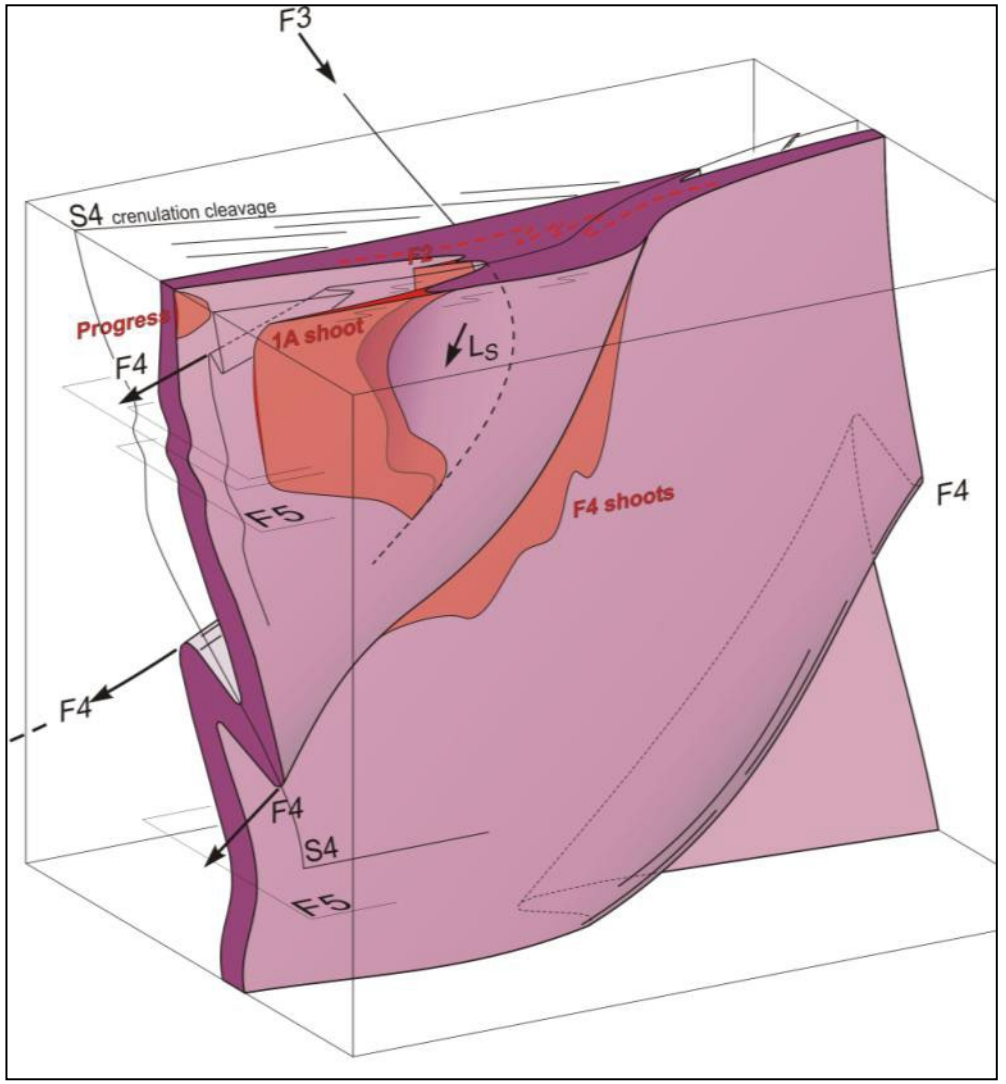
Sulfide accumulation in fold hinges

Cassini block model - *Looking E*





McFarlane et al., (2021)



Perseverance block model - *Looking SE* - Duuring et al., (2010)

Conclusions

- New stratigraphy – critical for 3D modelling
  - Lateral variation in magmatic processes – crustal evolution and early structures
- Tectonic/structural repetition of M/UM stratigraphy
  - Thrust repetitions developing along rheological contrasts
  - Earlier deformation characterised by foliation parallel to lithological contacts around the dome
- Clear distinction of overprinting planar foliation associated with macroscale folding only visible at Cassini, Voyce and regional structural datasets in the north of the dome
  - associated with protracted ENE-WSW to WNW-ESE shortening
  - More extensive folding, late low-angle thrusting and localised strike slip faulting developing on the eastern limb, particularly in the SE
  - Intense dip slip (top up to ENE) and oblique-slip noted on western limb
- Preservation vs mechanical/hydrothermal remobilisation
  - Preservation of magmatic channels
  - Diverse structural settings of mineralisation
- Limitations of 3D geological modelling
  - Issues with reproducibility, time and scalability
  - Need clear marker horizons for delineation of fault blocks and relative offset

Thank you

Helen McFarlane – helen.mcfarlane@csiro.au
Peter Schaubs – peter.schaubs@csiro.au