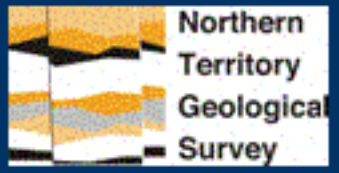
Collaborative GA-PIRSA-NTGS-GSWA studies

Important Contributions From:

Primary Industries and Resources of South Australia

Northern Territory Geological Survey

Geological Survey of Western Australia

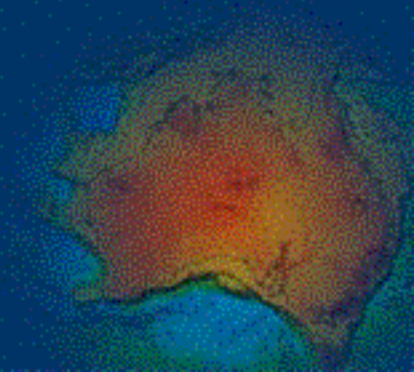


Australian Government

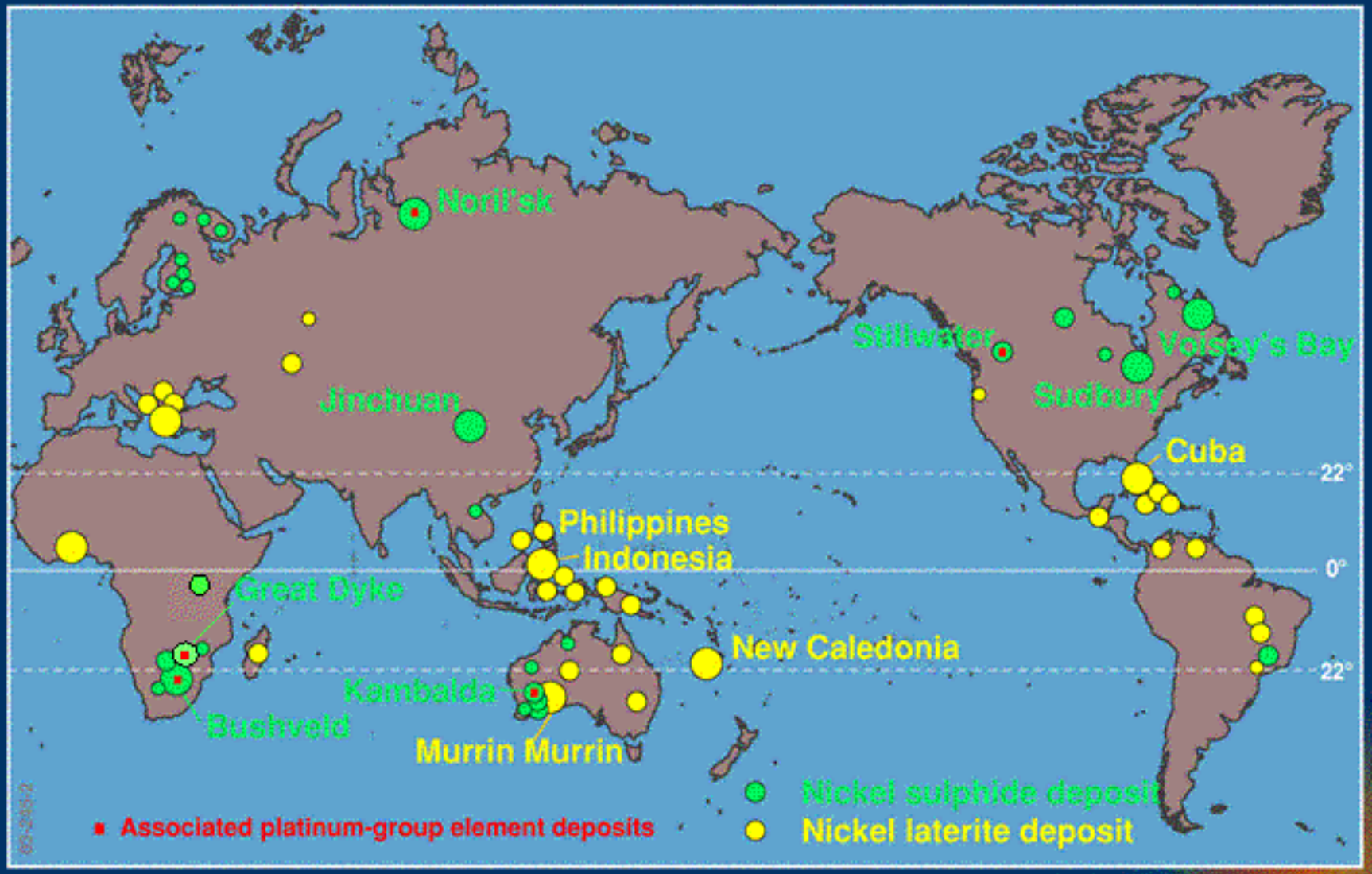
Geoscience Australia

Contents

- Distribution, production & resources
- Forces driving exploration
- Major Ni-Cu sulphide deposits/prospects
  Kambalda, Lake Harris, Sally Malay, McIntosh, Radio Hill, Nebo-Babel, Andrew Young Hills, Avebury
- Favourable mineralising elements & exploration potential

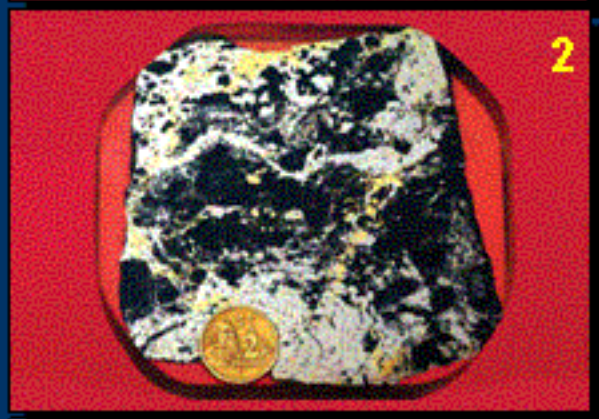


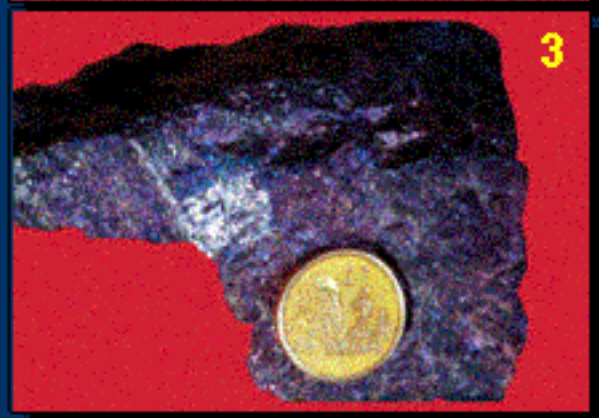
Major Nickel Deposits

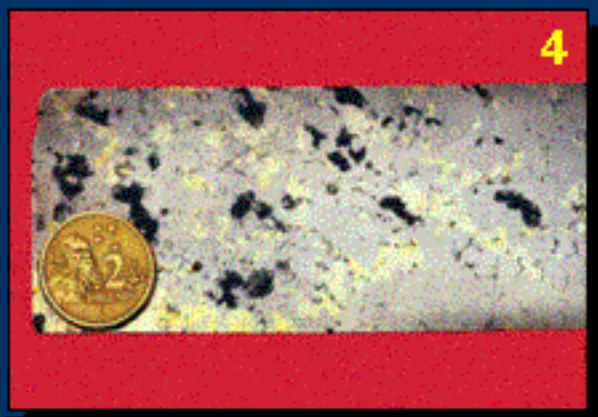


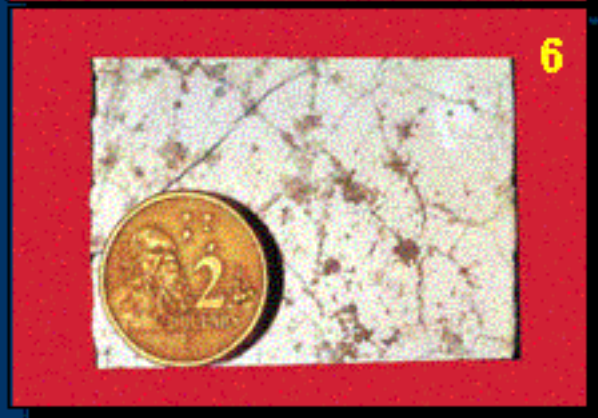
Modified from: Elias 2002

Massive Ni-Cu-Co Sulphide Ores









1. Voisey's Bay
2. Sudbury
3. Noril'sk

4. Radio Hill
5. Sally Malay
6. Honeymoon Well

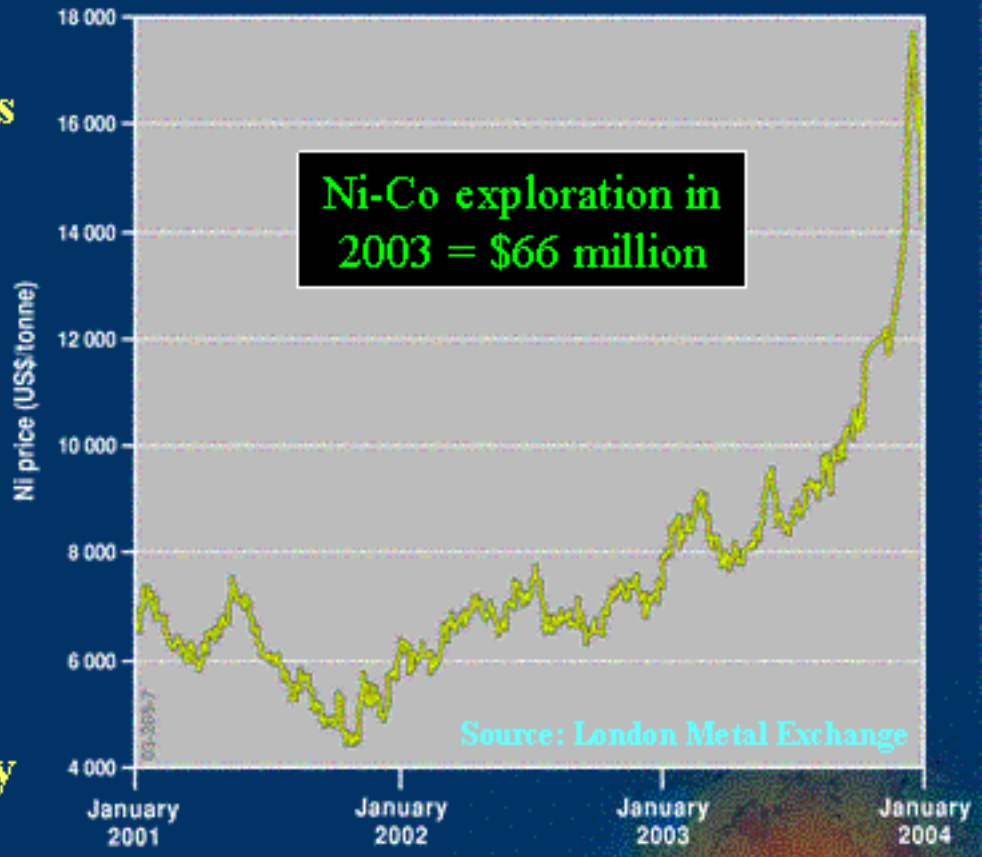
Nickel 'Boom' in Australia

Exploration successes since 2002:

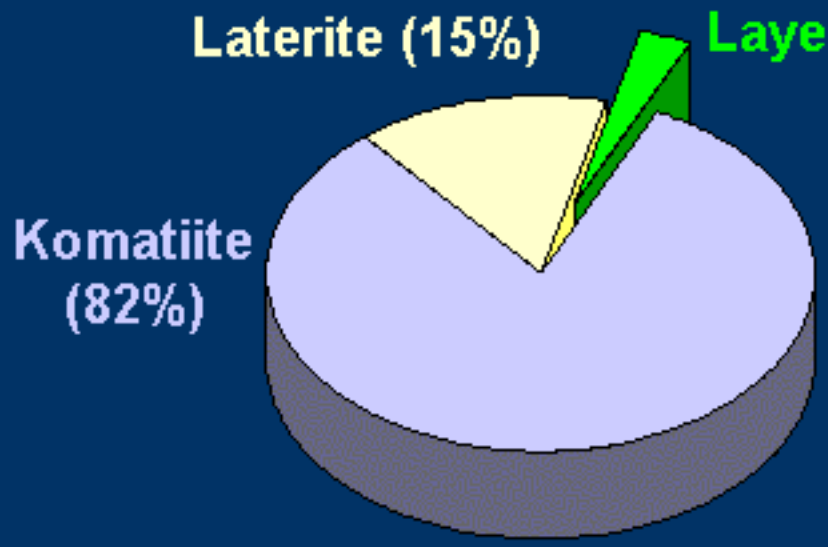
- Increased resources at previously known Archaean komatiite deposits
- Delineation of deep and covered mineralised komatiite sequences
- New mineralised Proterozoic mafic-ultramafic intrusions

Exploration drivers:

- Discoveries (Nebo-Babel) and recognition of new styles of mineralisation (Avebury: ?skarn)
- Highest Ni prices (↑ Pt & Co) in 14 y

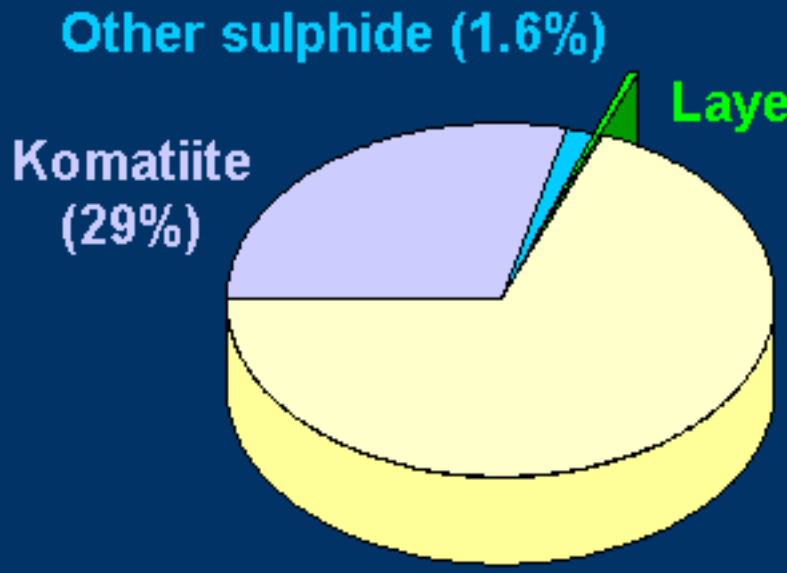


Australian Nickel Production

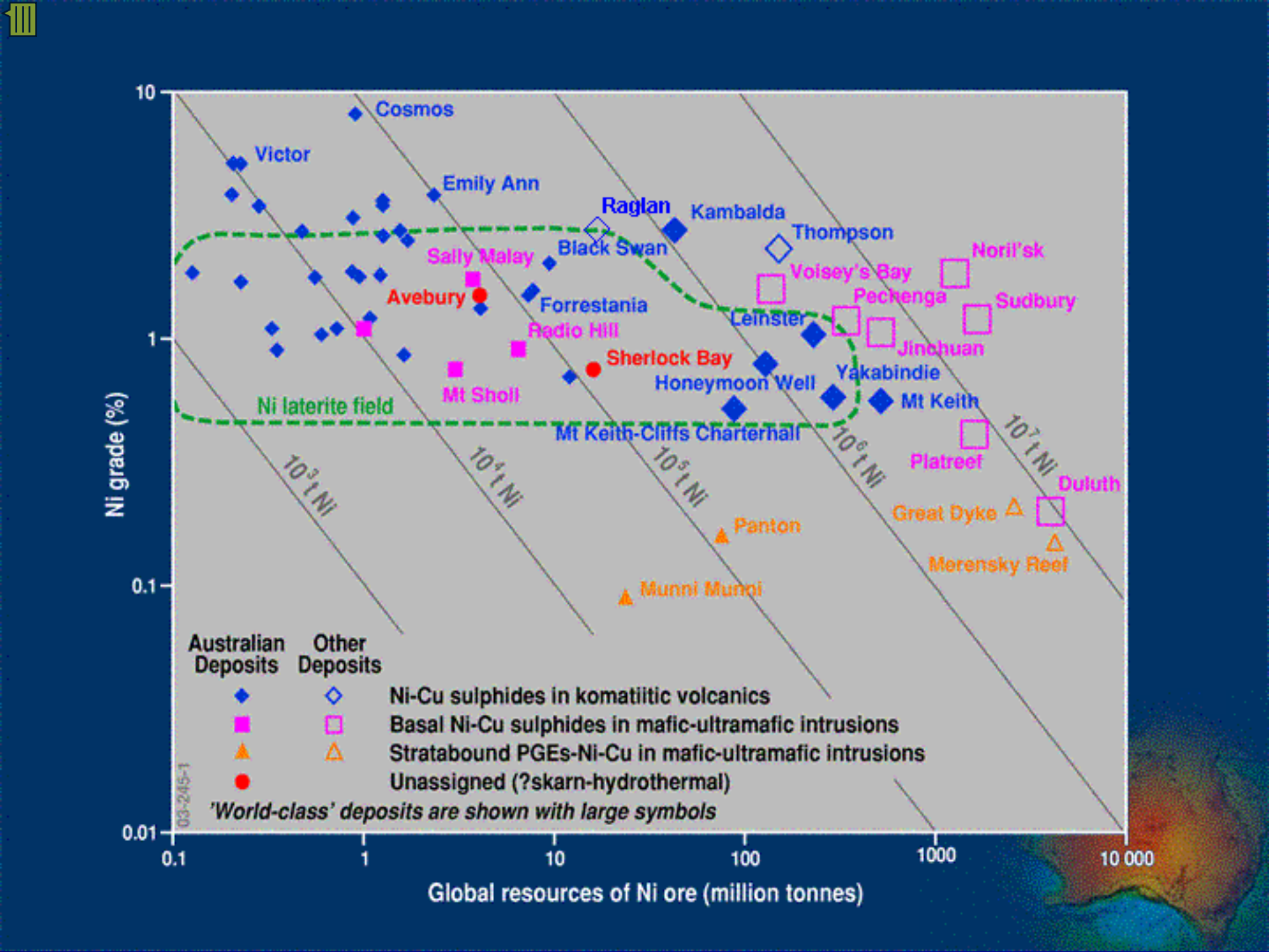


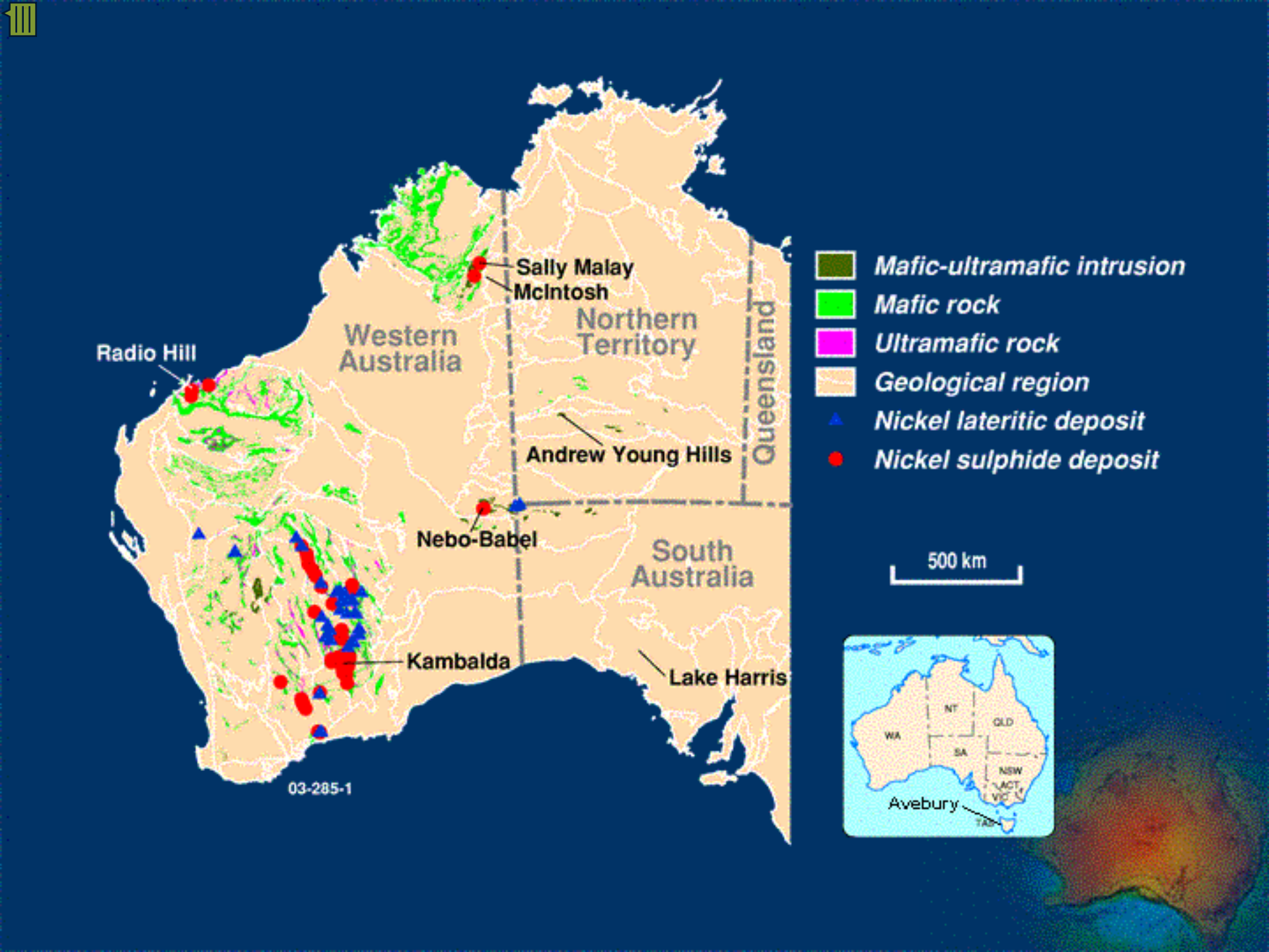
Australia produces ~15% of the world's Ni (1.3 Mt) → # 2 after Russia

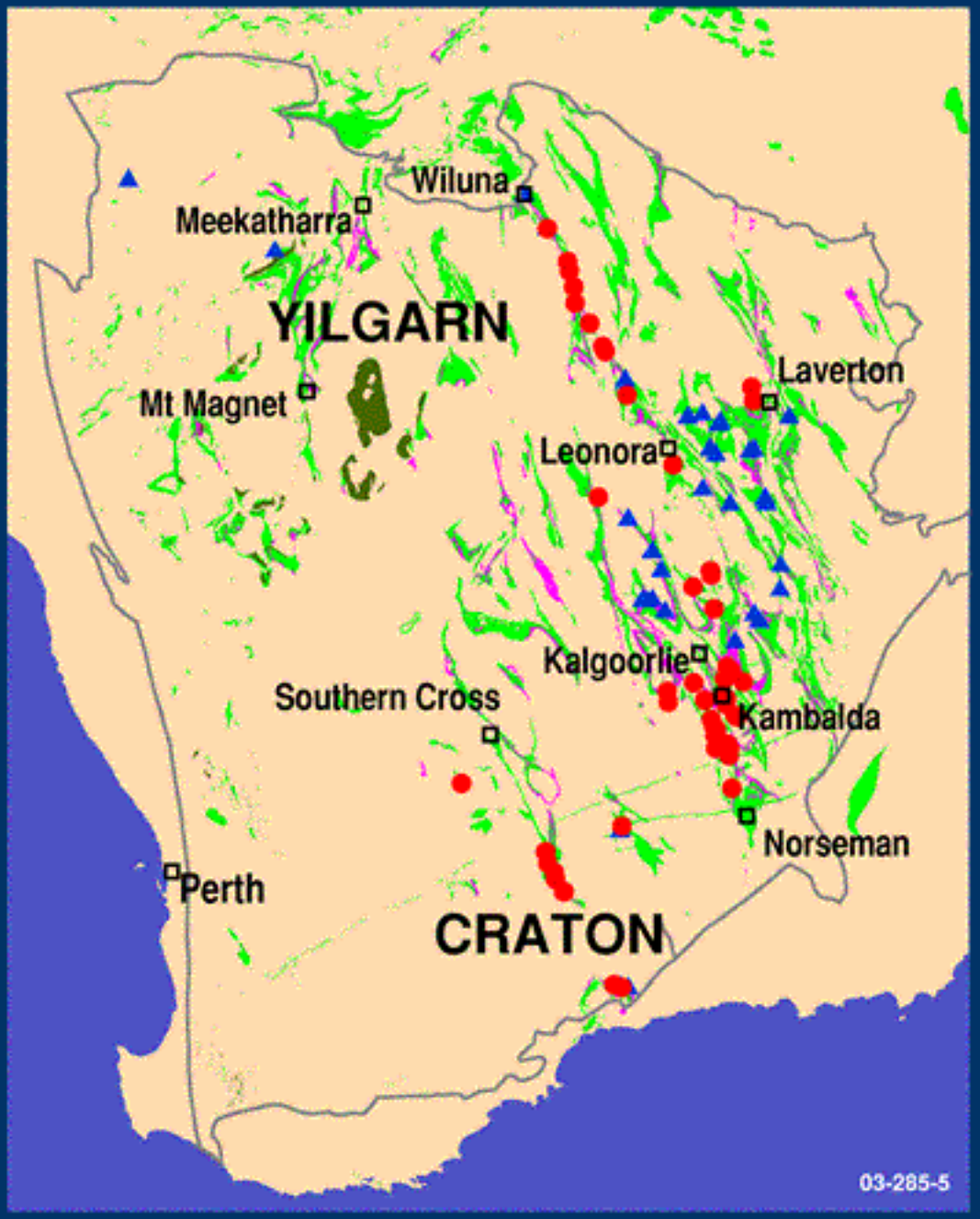
Australian Nickel Resources



Source: GA & ABARE


Ni grade (%)
Global resources of Ni ore (million tonnes)
10
1
0.1
0.01
0.1
1
10
100
1000
10 000
Cosmos
Victor
Emily Ann
Raglan
Kambalda
Thompson
Black Swan
Sally Malay
Avebury
Forrestania
Radio Hill
Sherlock Bay
Mt Sholl
Honeymoon Well
Yakabindie
Mt Keith
Leinster
Voisey's Bay
Pechenga
Noril'sk
Sudbury
Jinchuan
Platreef
Duluth
Great Dyke
Merensky Reef
Panton
Munni Munni
Ni laterite field
Mt Keith-Cliffs Charterhall
10^3 t Ni
10^4 t Ni
10^5 t Ni
10^6 t Ni
10^7 t Ni
Australian Deposits
Other Deposits
Ni-Cu sulphides in komatiitic volcanics
Basal Ni-Cu sulphides in mafic-ultramafic intrusions
Stratabound PGEs-Ni-Cu in mafic-ultramafic intrusions
Unassigned (?skarn-hydrothermal)
'World-class' deposits are shown with large symbols
03-245-1


Sally Malay
McIntosh
Radio Hill
Western Australia
Northern Territory
Queensland
Andrew Young Hills
Nebo-Babel
South Australia
Kambalda
Lake Harris
03-285-1
Mafic-ultramafic intrusion
Mafic rock
Ultramafic rock
Geological region
Nickel lateritic deposit
Nickel sulphide deposit
500 km
NT
QLD
WA
SA
NSW
ACT
VIC
TAS
Avebury

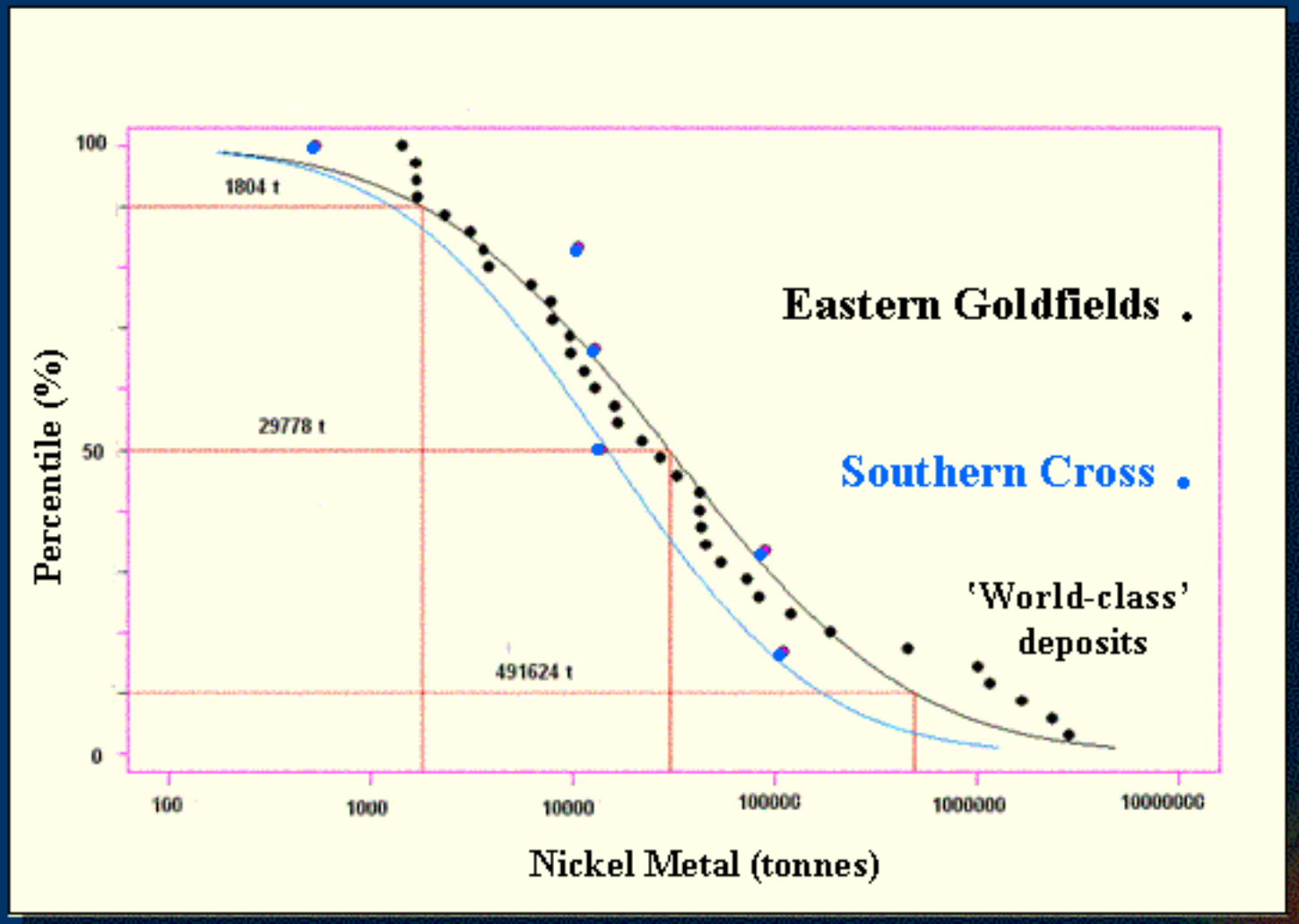


Kambalda (2700 Ma): Yilgarn Craton

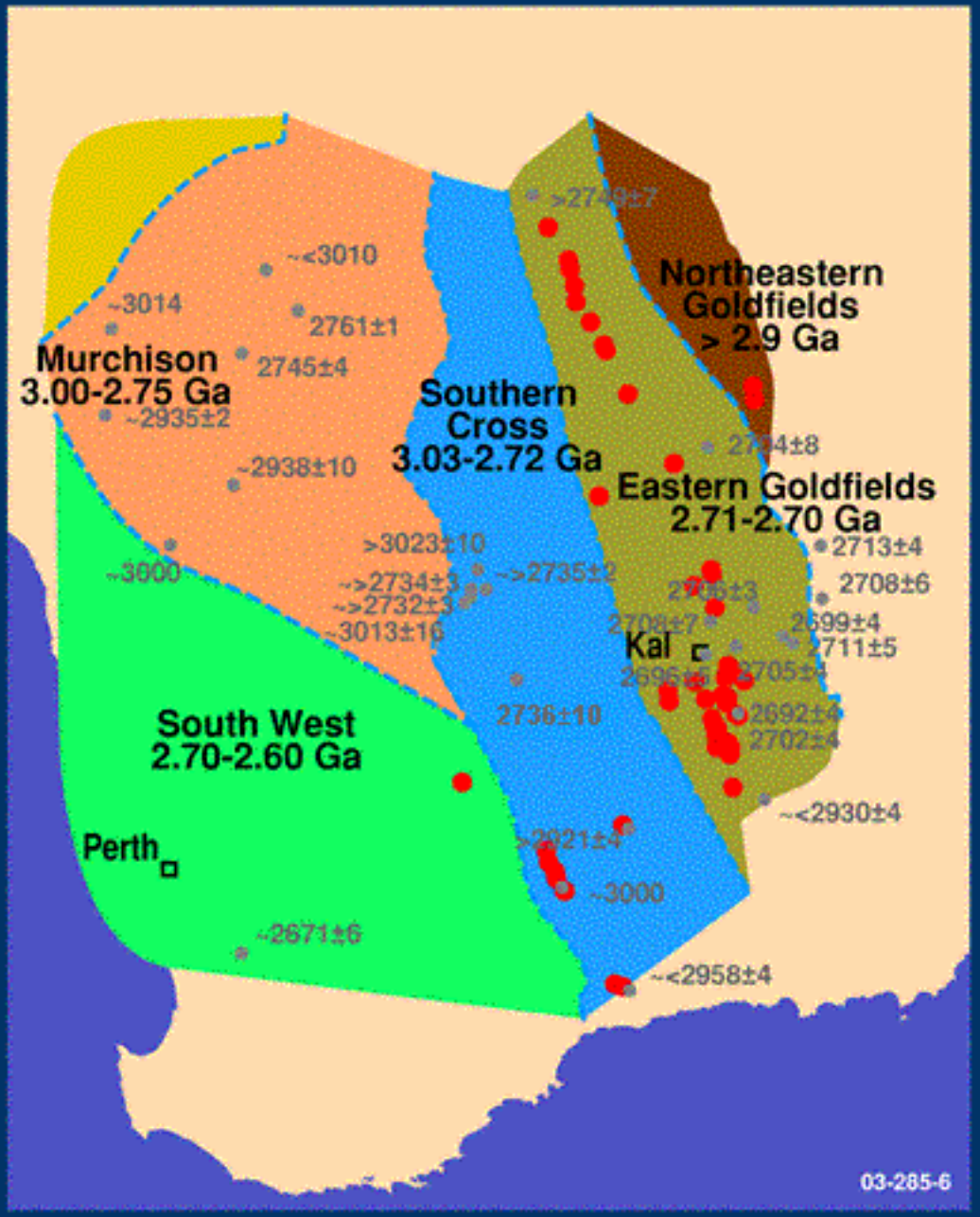
- *Mafic-ultramafic intrusion*
- *Mafic rock*
- *Ultramafic rock*
- *Nickel lateritic deposit*
- *Nickel sulphide deposit*

250 km

Nickel potential of the Southern Cross Province?



Geochronology of Komatiites



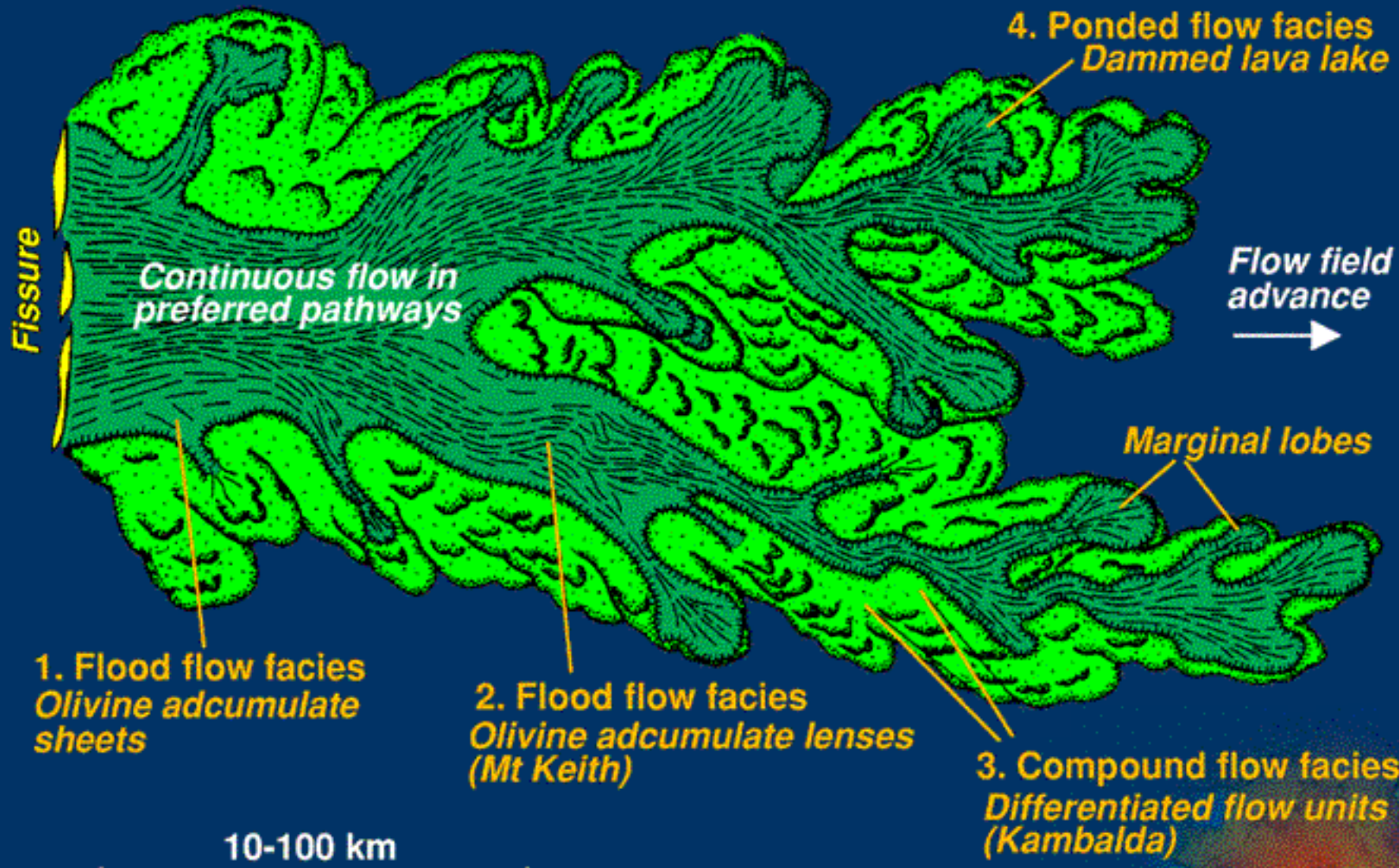
Terrane boundary
(modified after Tyler & Hocking 2002)

Nickel sulphide deposit

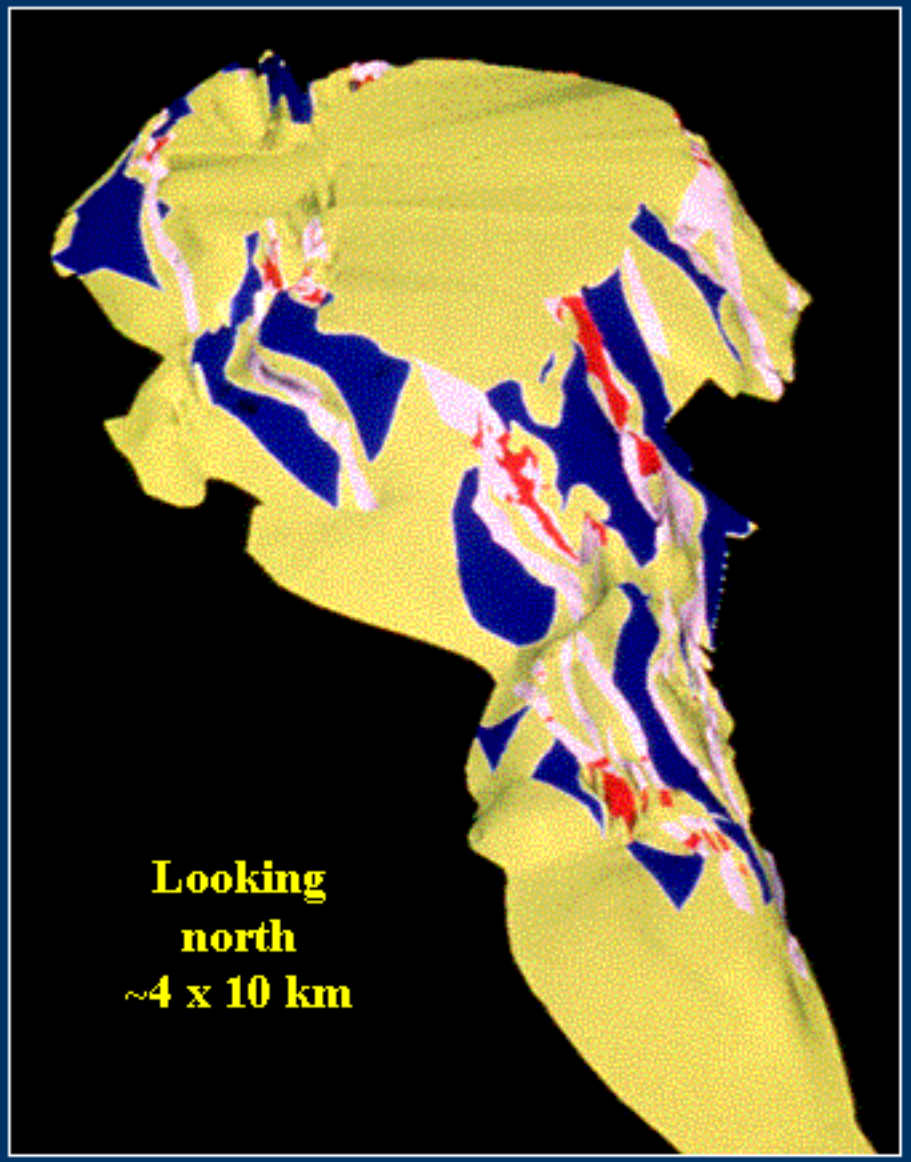
250 km

All ages shown: U-Pb zircon

Volcanology of Komatiite Flows



Dowling & Hill 1998



3-D Visualisation: Kambalda Dome

Ore shoots

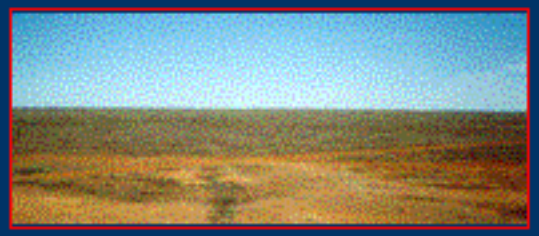
Mineralised sediments

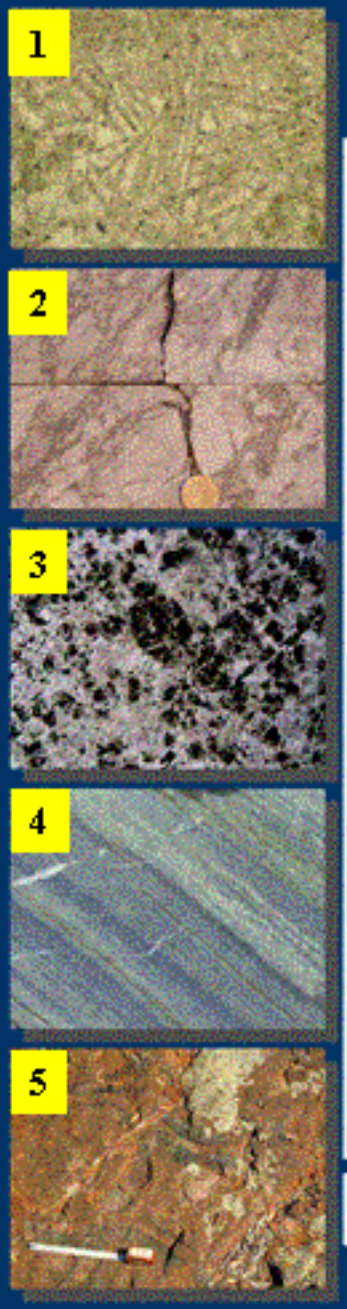
Contact sediments

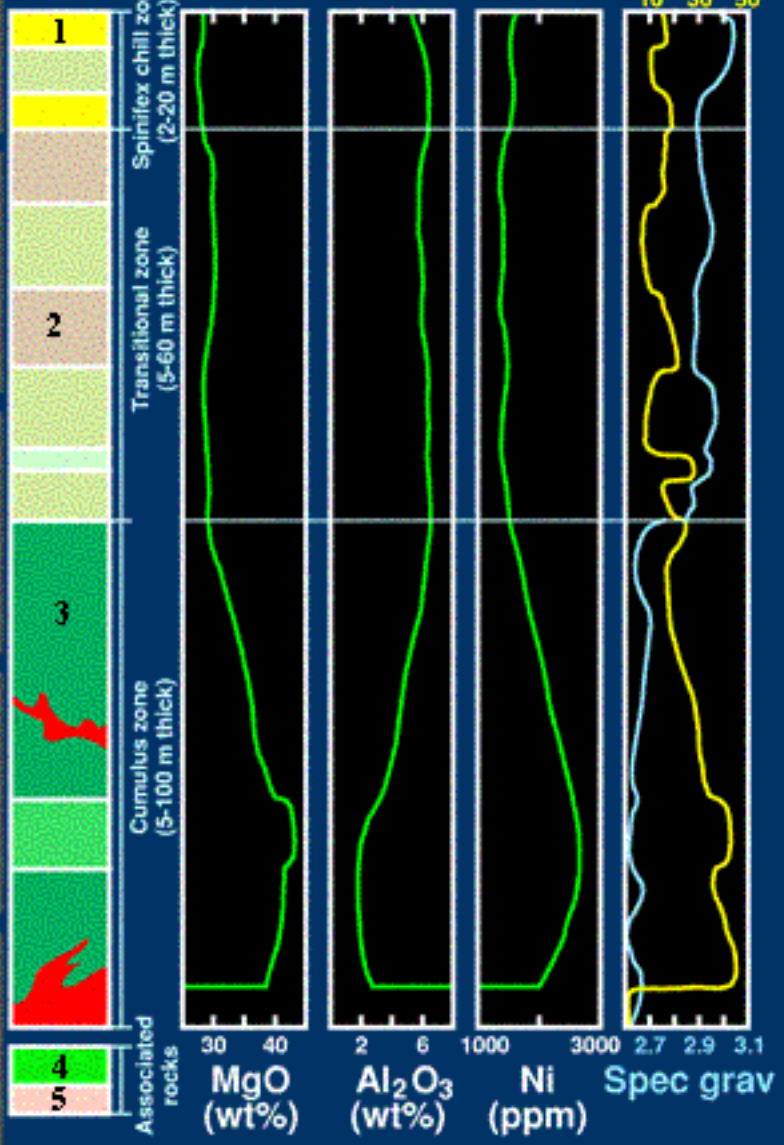
Lunnon Basalt-footwall

Image: Fractal Graphics & WMC Ltd
Data: 4000 DDHs & 70 mine sections

Lake Harris Komatiite (2520 Ma): Gawler Craton





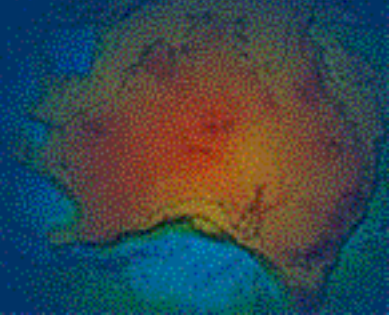


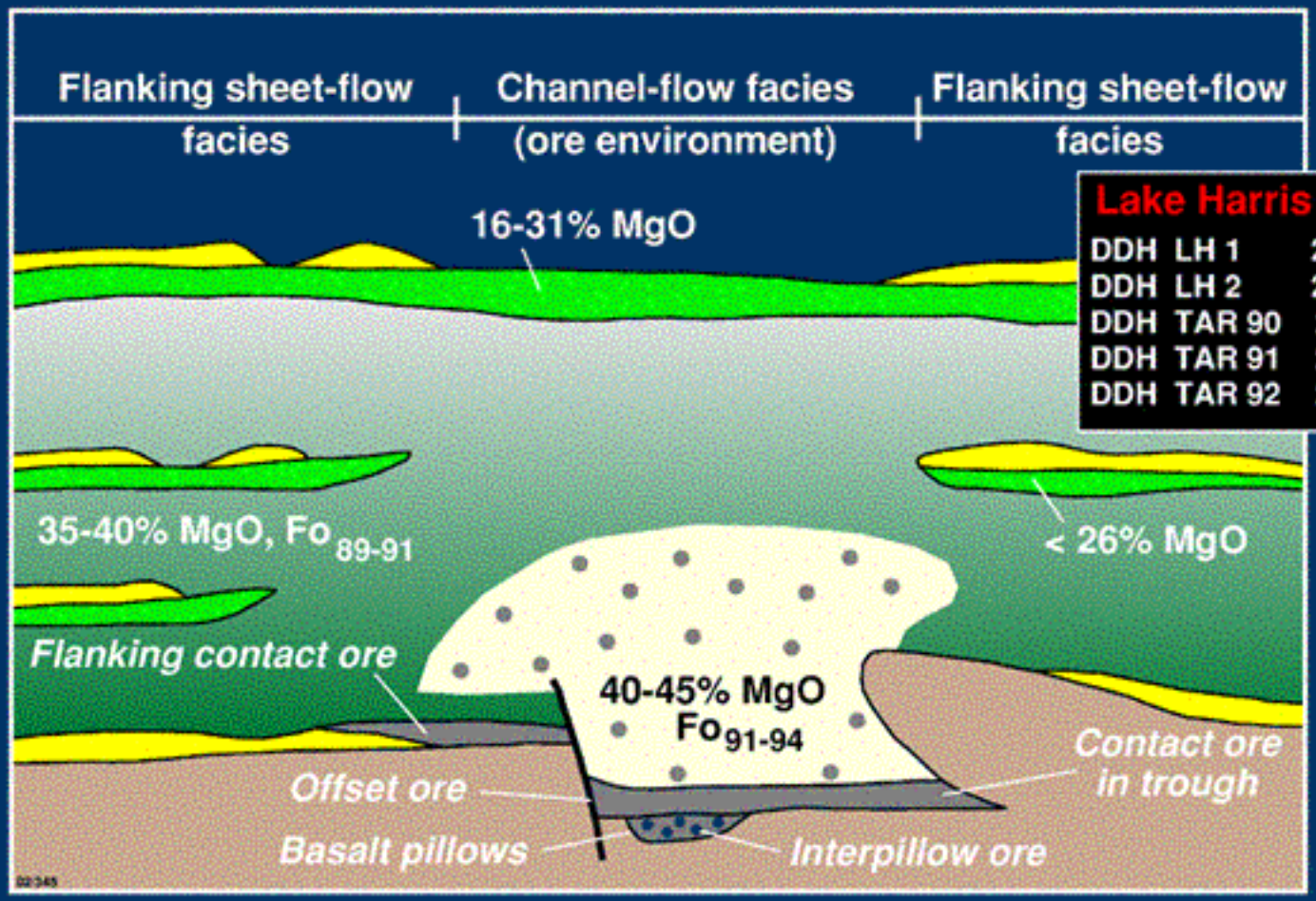
Lake Harris Komatiite

- *Komatiite with random platy spinifex*
- *?Flow top breccia*
- *Aphyric komatiite*
- *Komatiite with no relict texture*
- *Olivine adcumulate*
- *Olivine ortho- and mesocumulate*

Associated rocks

- *Felsic rocks (quartz diorite, dacite, chert)*
- *Banded iron formation, metasediments*
- *Pillowed metabasalt*





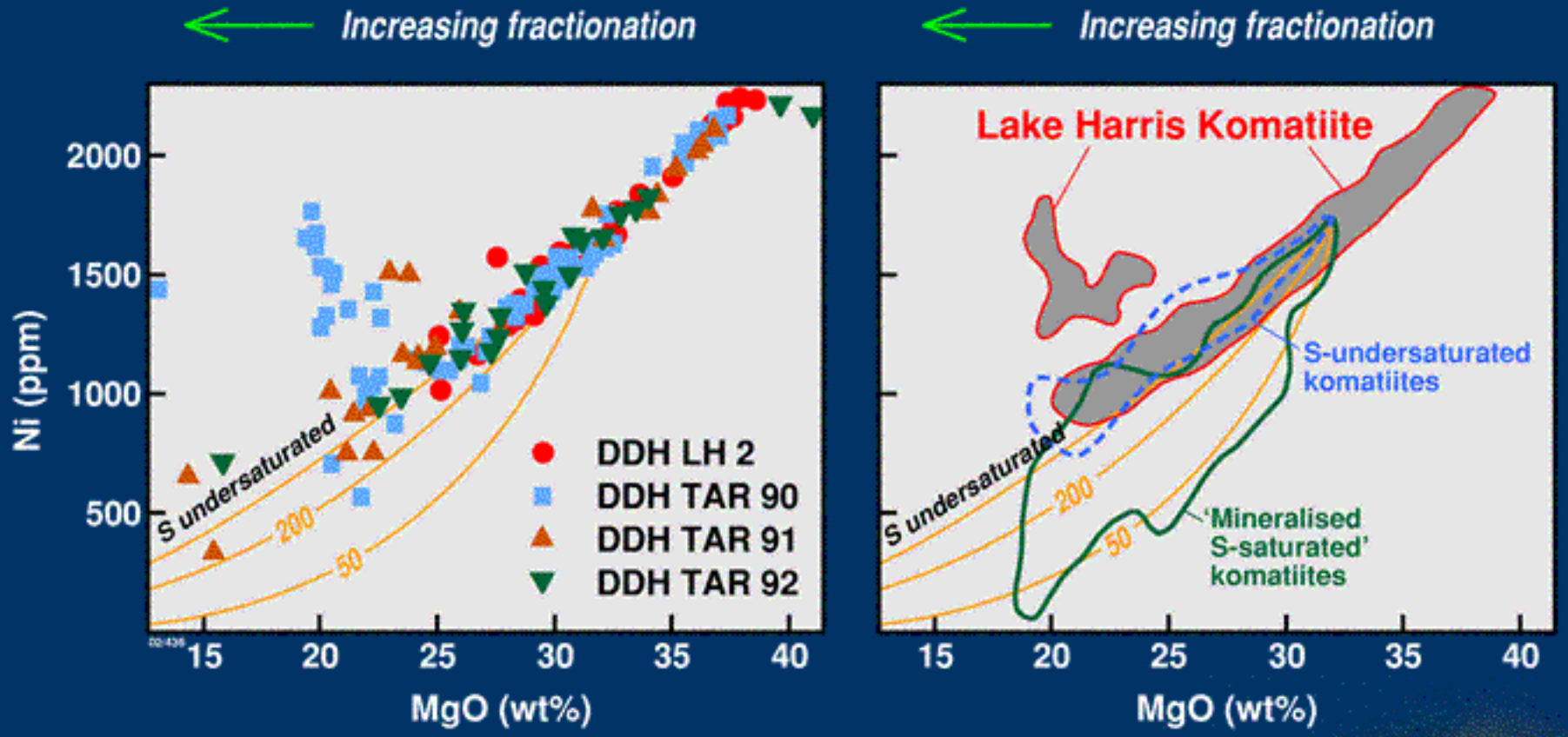
Lake Harris Komatiite

DDH LH 1	27-43% MgO,	(no olivine)
DDH LH 2	25-43% MgO,	Fo 73-85
DDH TAR 90	21-41% MgO,	Fo 83-89
DDH TAR 91	23-41% MgO,	Fo 73-89
DDH TAR 92	20-41% MgO,	Fo 83-88

- *Flow top*
- *Thin (5-100 m) differentiated komatiite flows*
- *Interflow sediments*
- *Disseminated Ni-Cu ore*
- *Massive Ni-Cu ore*
- *Basalt*

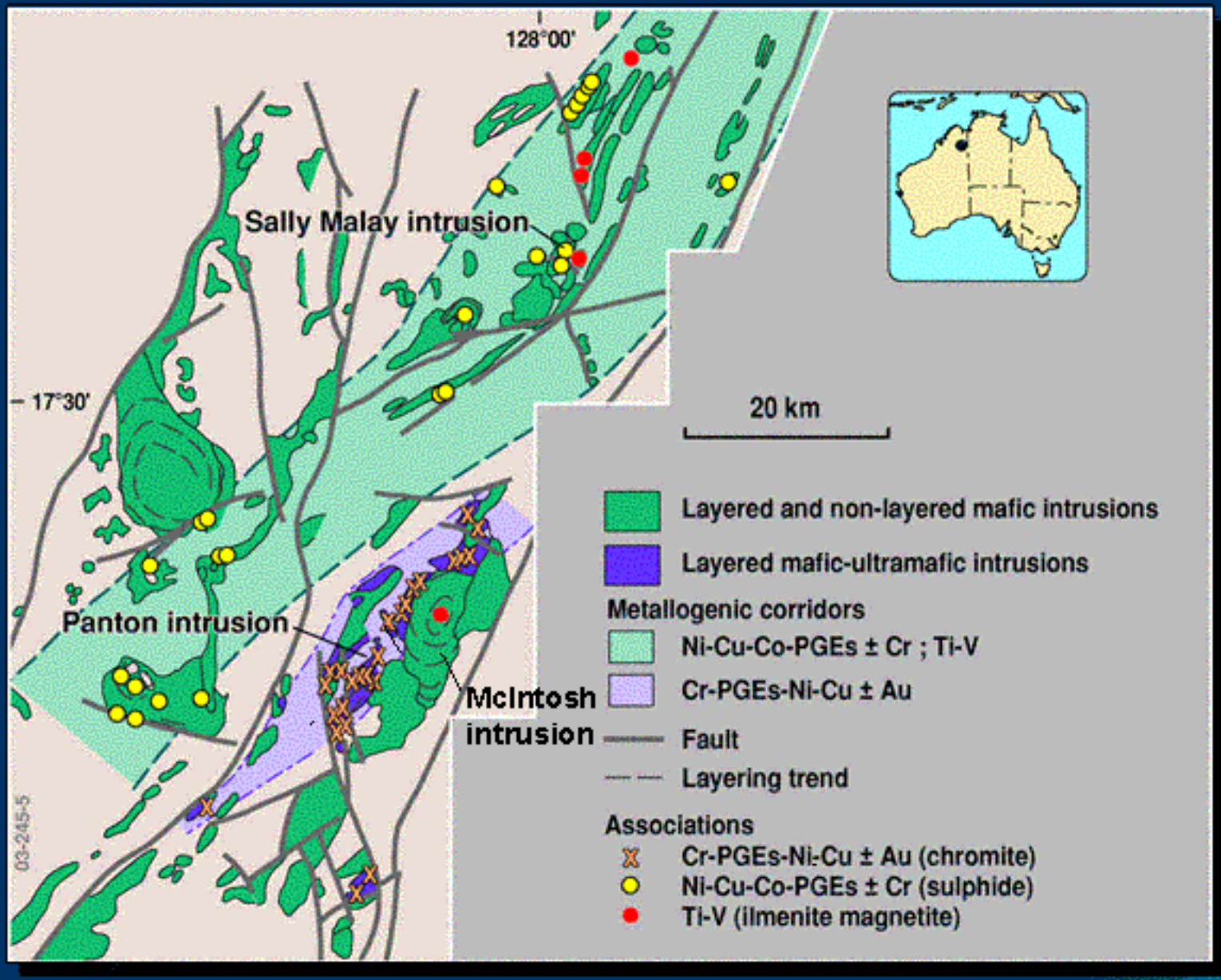
Kambalda data: Lesher 1989

S-saturation Status

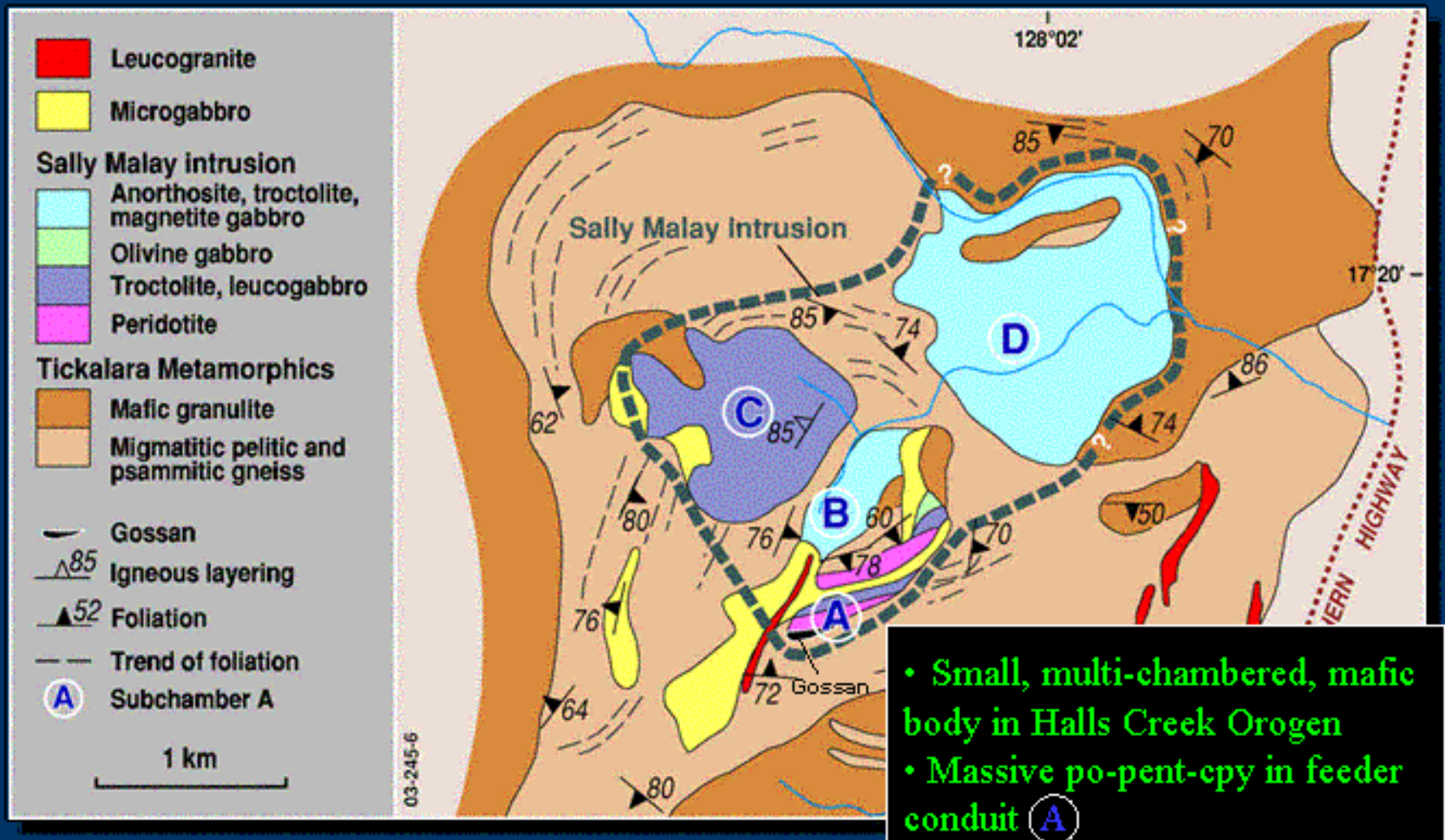


Lake Harris data: Hoatson et al 2004
Other komatiite data: Naldrett 1989

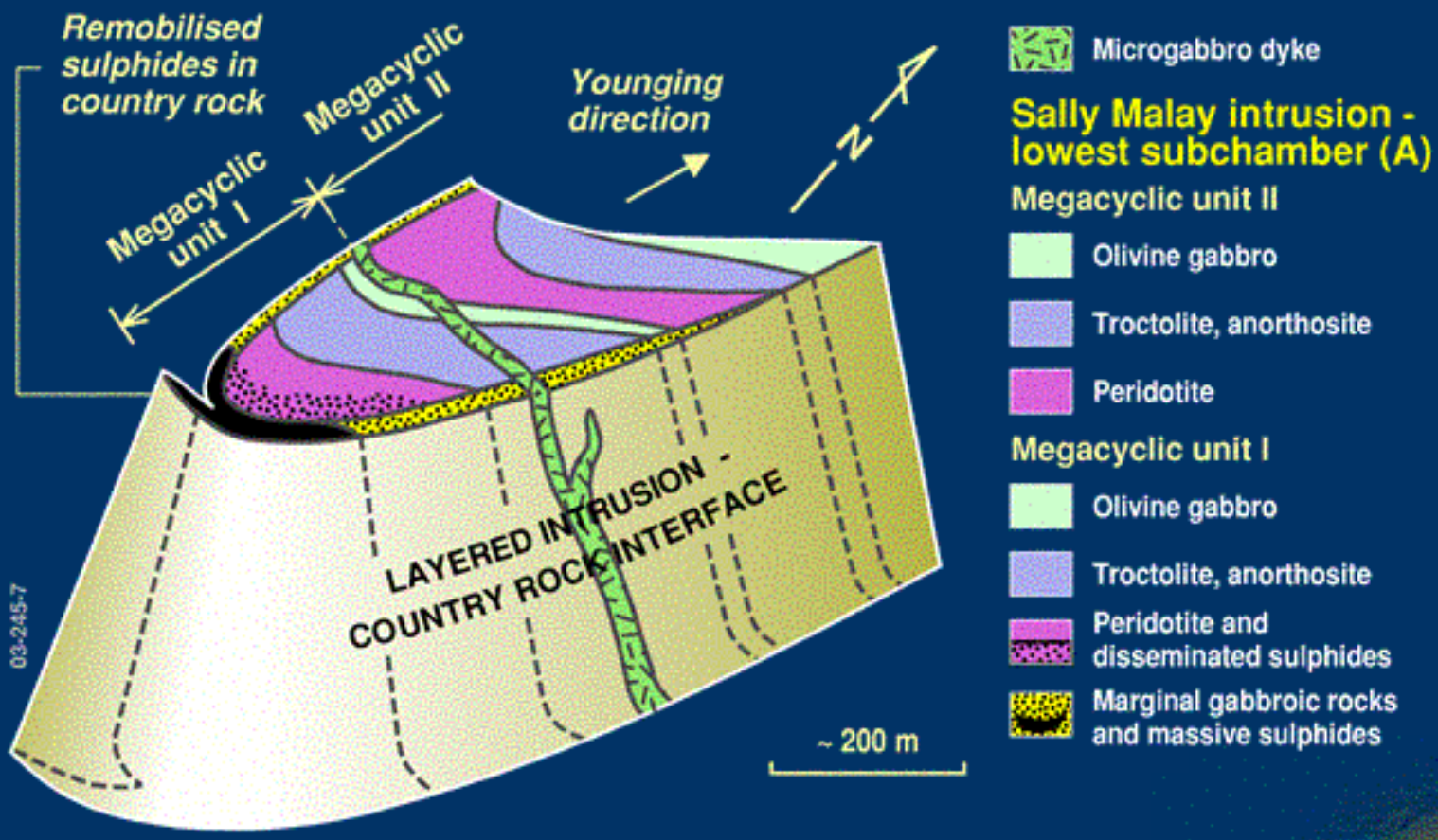
Proterozoic Mafic-Ultramafic Intrusions: Halls Creek Orogen



Sally Malay Intrusion (1845 Ma)

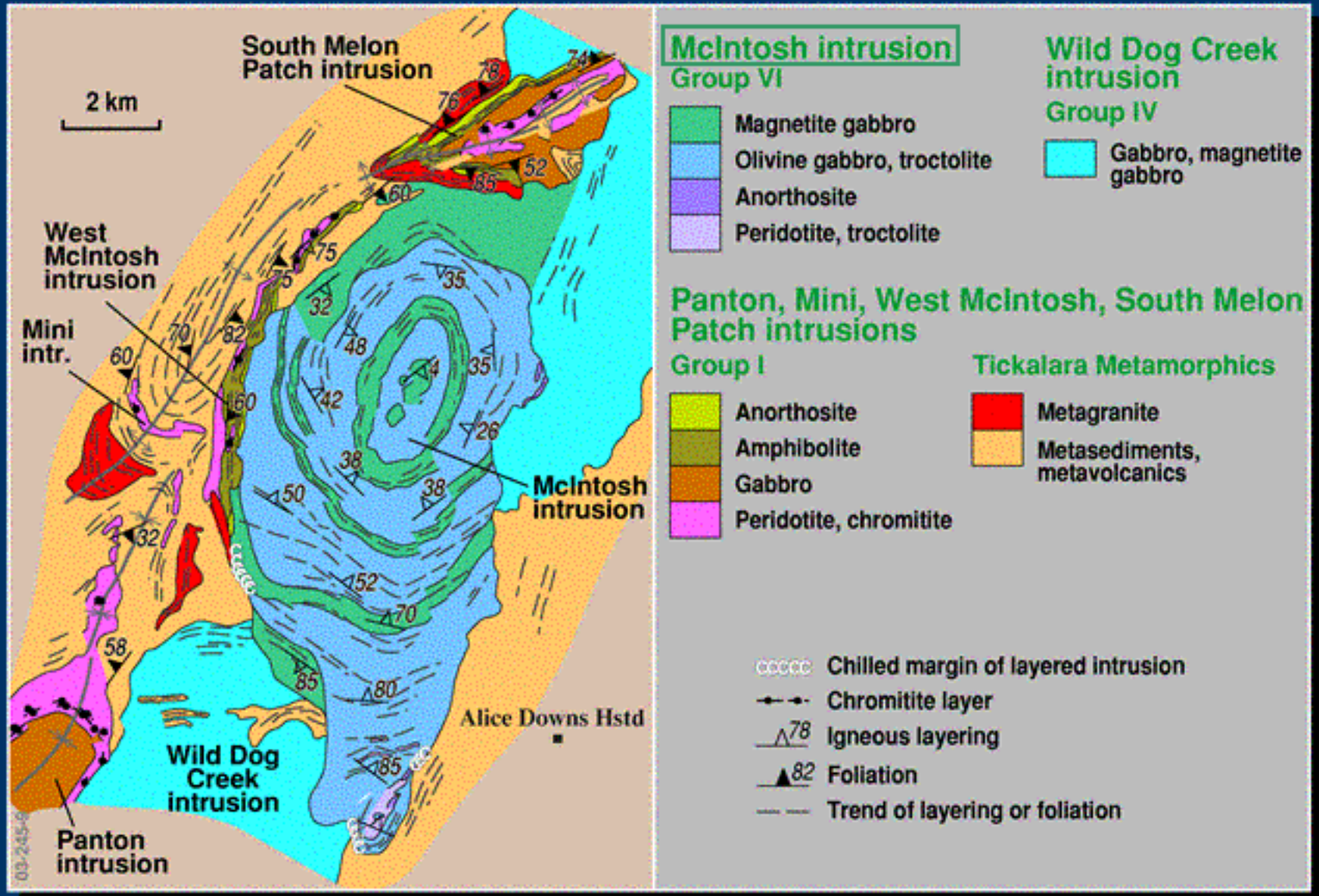


- Small, multi-chambered, mafic body in Halls Creek Orogen
- Massive po-pent-cpy in feeder conduit (A)
- 3.7 Mt @ 1.7% Ni, 0.7% Cu, 0.1% Co; production 2004


Remobilised sulphides in country rock
Megacyclic unit II
Megacyclic unit I
Younging direction
N
LAYERED INTRUSION - COUNTRY ROCK INTERFACE
~ 200 m
03-245-7
Microgabbro dyke
Sally Malay intrusion - lowest subchamber (A)
Megacyclic unit II
Olivine gabbro
Troctolite, anorthosite
Peridotite
Megacyclic unit I
Olivine gabbro
Troctolite, anorthosite
Peridotite and disseminated sulphides
Marginal gabbroic rocks and massive sulphides

03-245-7

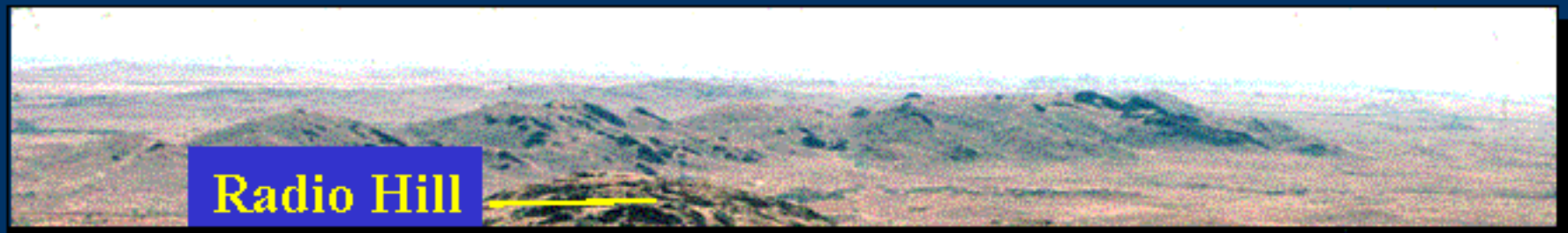
McIntosh Intrusion (1830 Ma)

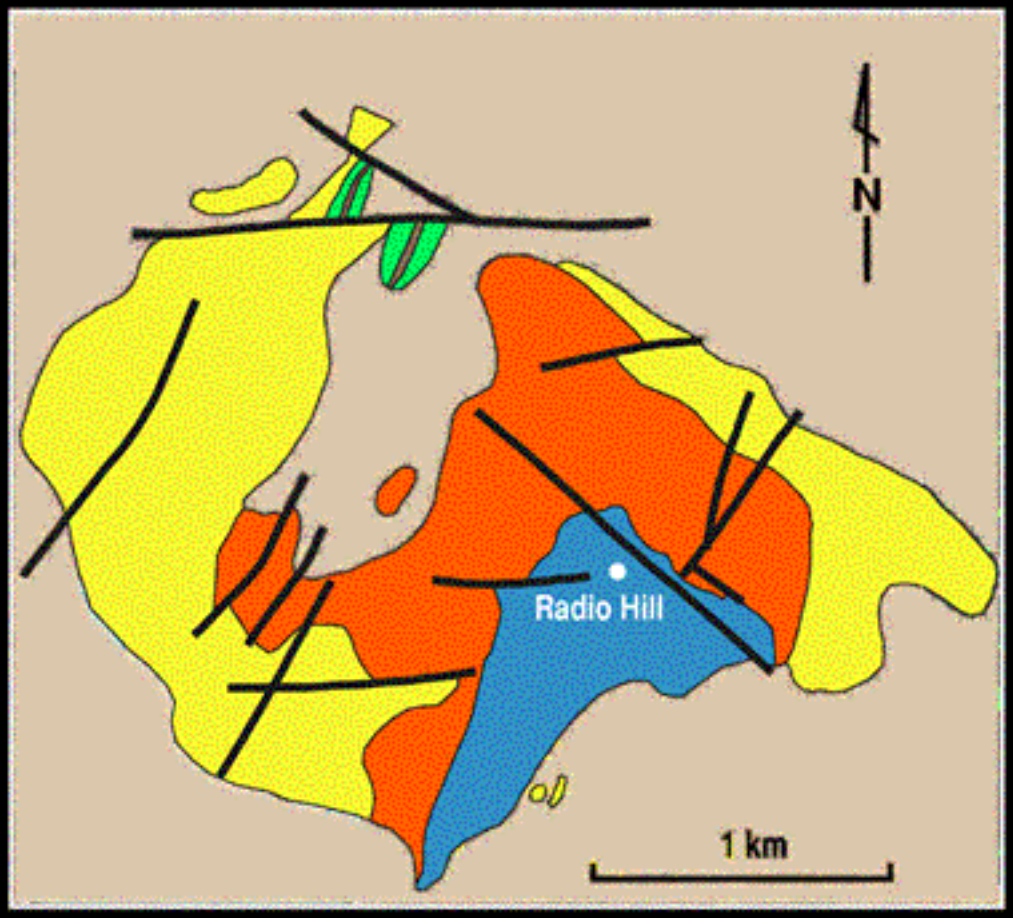

South Melon Patch intrusion
2 km
West McIntosh intrusion
Mini intr.
McIntosh intrusion
Wild Dog Creek intrusion
Panton intrusion
Alice Downs Hstd
McIntosh intrusion
Group VI
Magnetite gabbro
Olivine gabbro, troctolite
Anorthosite
Peridotite, troctolite
Wild Dog Creek intrusion
Group IV
Gabbro, magnetite gabbro
Panton, Mini, West McIntosh, South Melon Patch intrusions
Group I
Anorthosite
Amphibolite
Gabbro
Peridotite, chromitite
Tickalara Metamorphics
Metagranite
Metasediments, metavolcanics
Chilled margin of layered intrusion
Chromitite layer
Igneous layering
Foliation
Trend of layering or foliation

Radio Hill Intrusion (2890 Ma): Pilbara Craton

- Small, differentiated, layered basinal body in west Pilbara Craton
- Massive sulphides in depressions of basal contact below thickest sequence of cumulates & in feeder conduit
- 4.2 Mt @ 1.35% Ni equivalent
- Voisey's Bay analogue

Radio Hill Intrusion (2890 Ma): Pilbara Craton



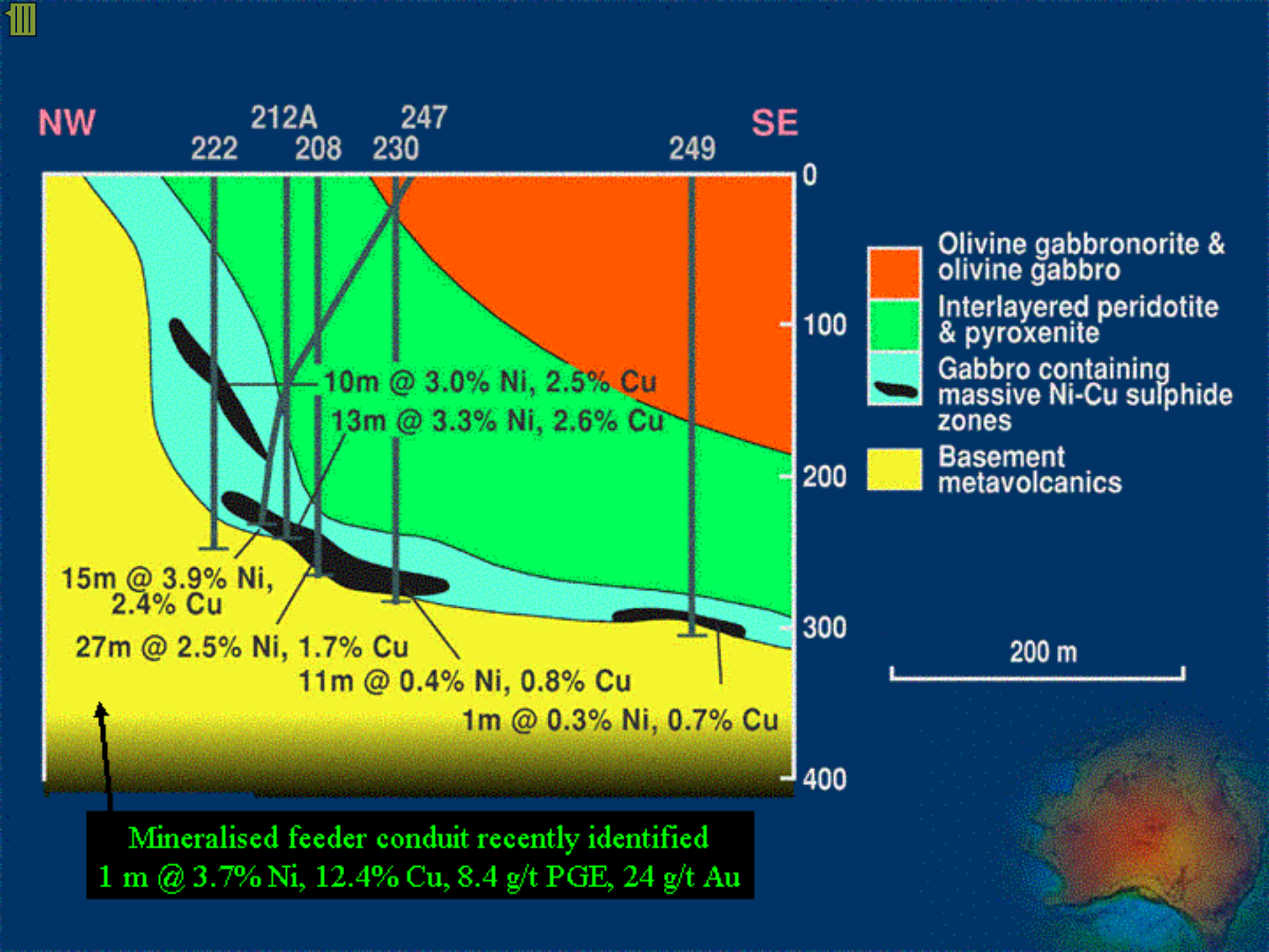


Quartz gabbro

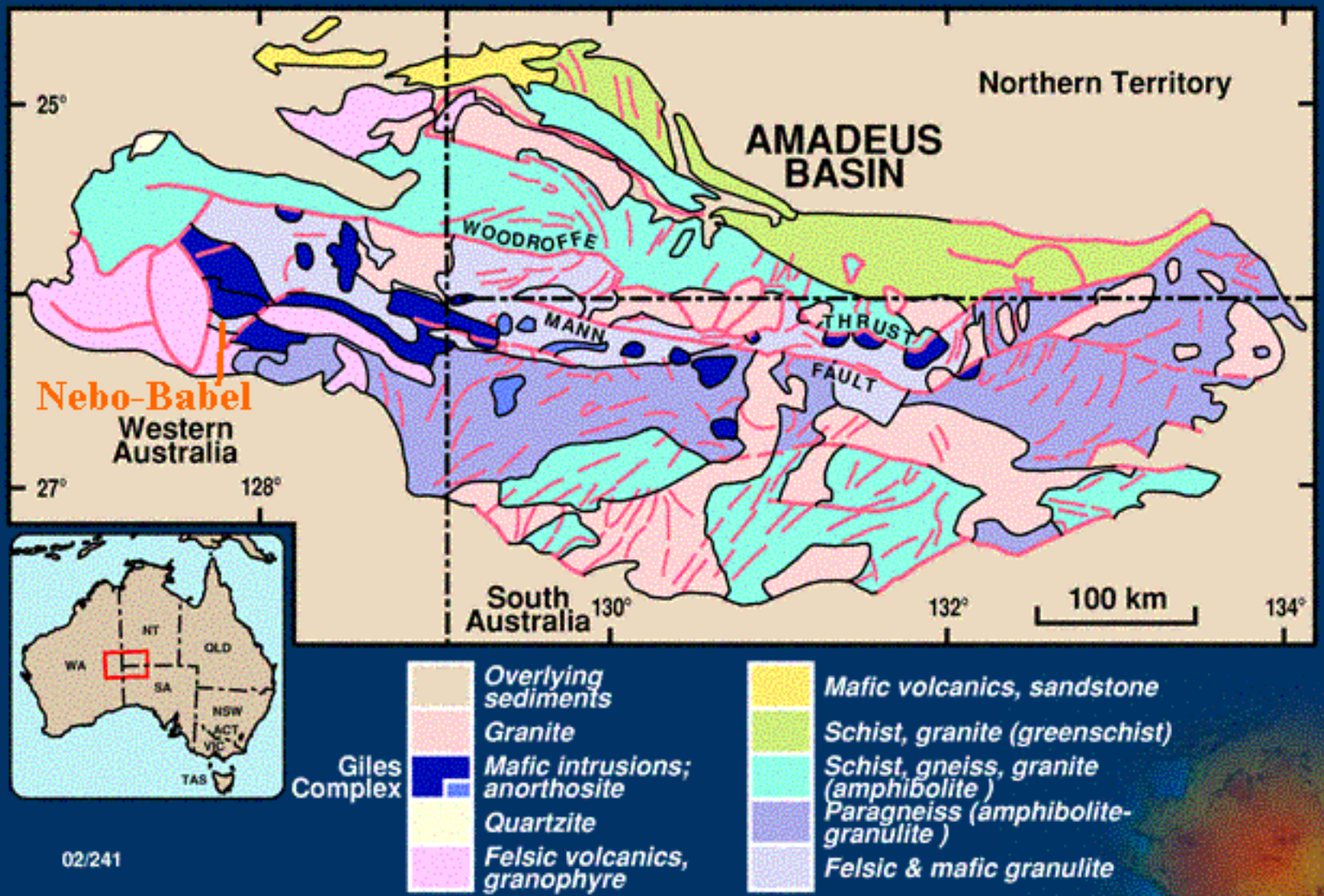
Olivine gabbronorite

Peridotite & pyroxenite Ni-Cu sulphides in marginal gabbro

Basement metavolcanics

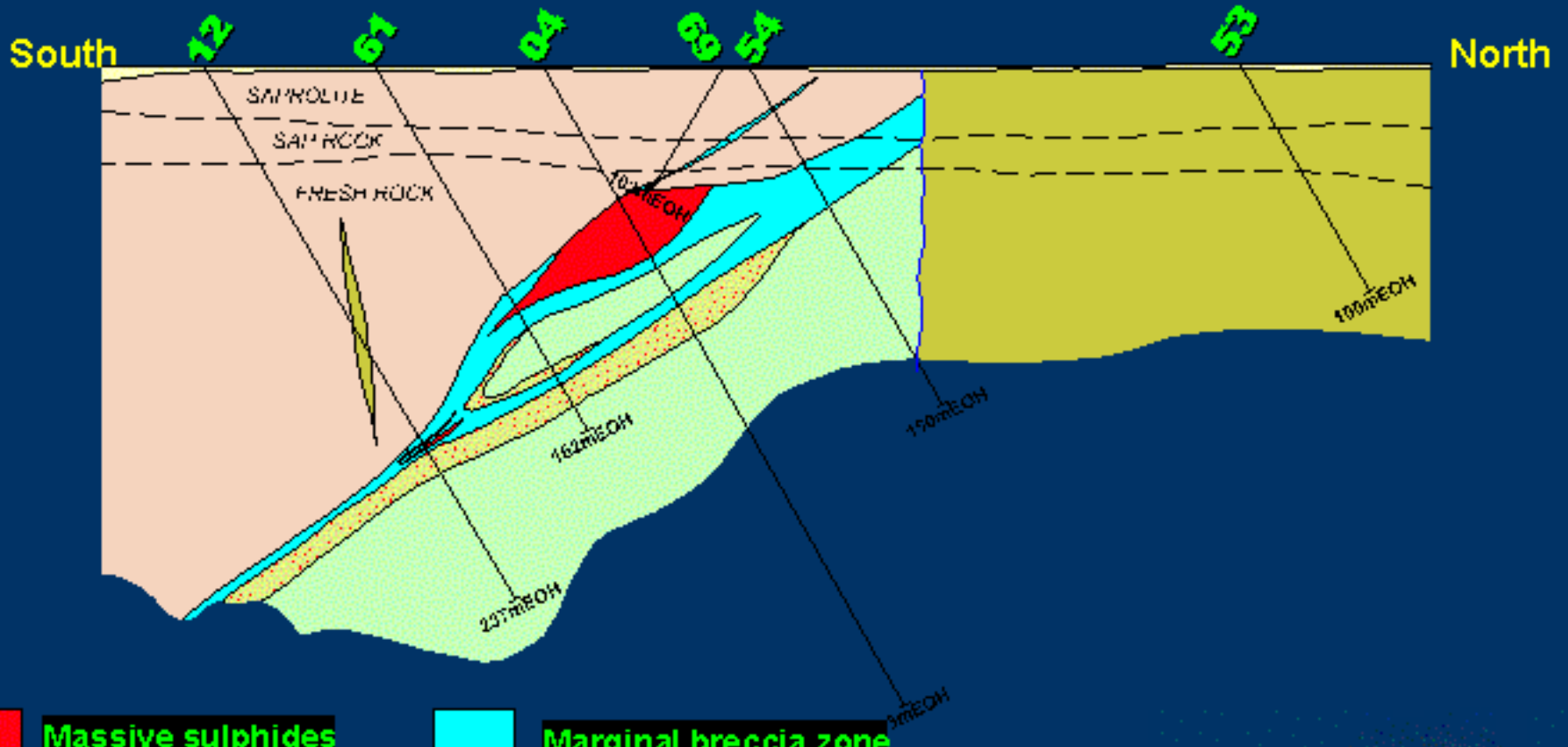

NW
222
212A
208
247
230
249
SE
0
100
200
300
400
10m @ 3.0% Ni, 2.5% Cu
13m @ 3.3% Ni, 2.6% Cu
15m @ 3.9% Ni, 2.4% Cu
27m @ 2.5% Ni, 1.7% Cu
11m @ 0.4% Ni, 0.8% Cu
1m @ 0.3% Ni, 0.7% Cu
Olivine gabbronorite & olivine gabbro
Interlayered peridotite & pyroxenite
Gabbro containing massive Ni-Cu sulphide zones
Basement metavolcanics
200 m
Mineralised feeder conduit recently identified
1 m @ 3.7% Ni, 12.4% Cu, 8.4 g/t PGE, 24 g/t Au

Nebo-Babel (~1080 Ma): Musgrave Block



02/241

Nebo: Drill Hole Cross-Section (372 700 m E)

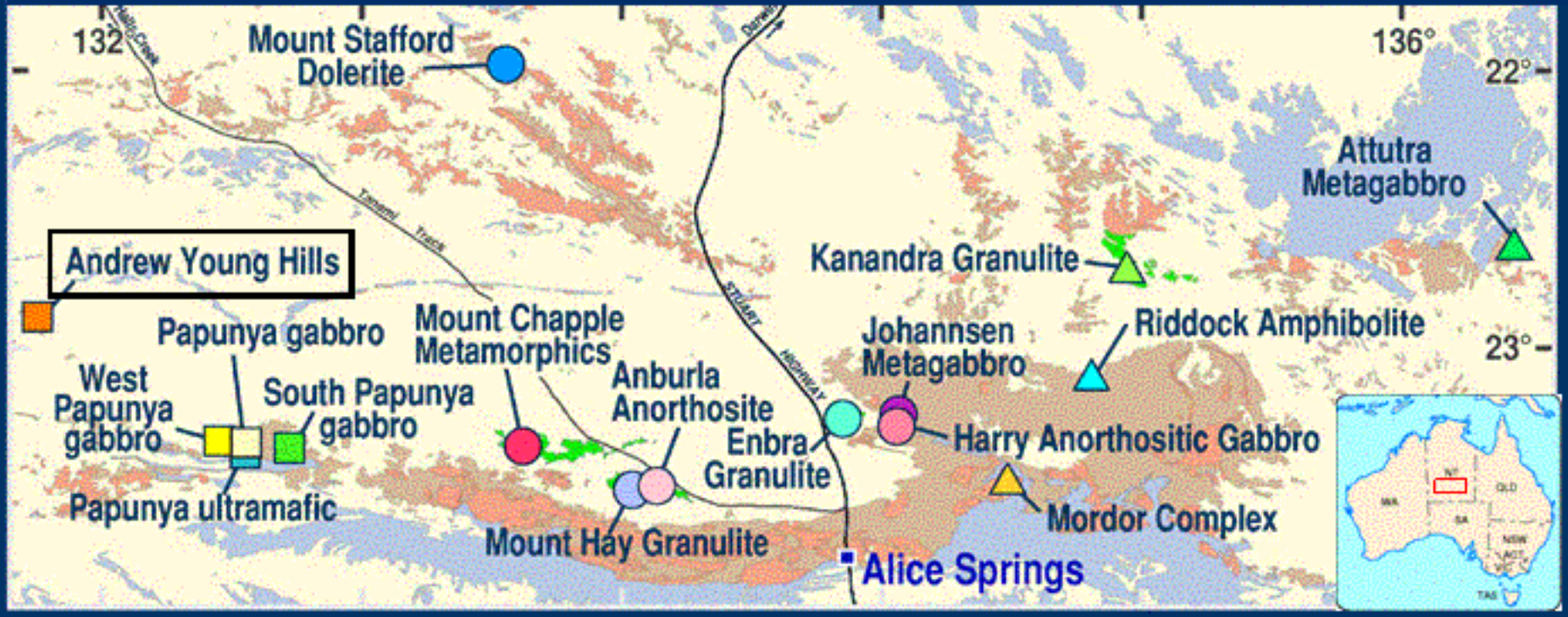


Source: J. Hronsky WMC Expl : MEGWA 2003

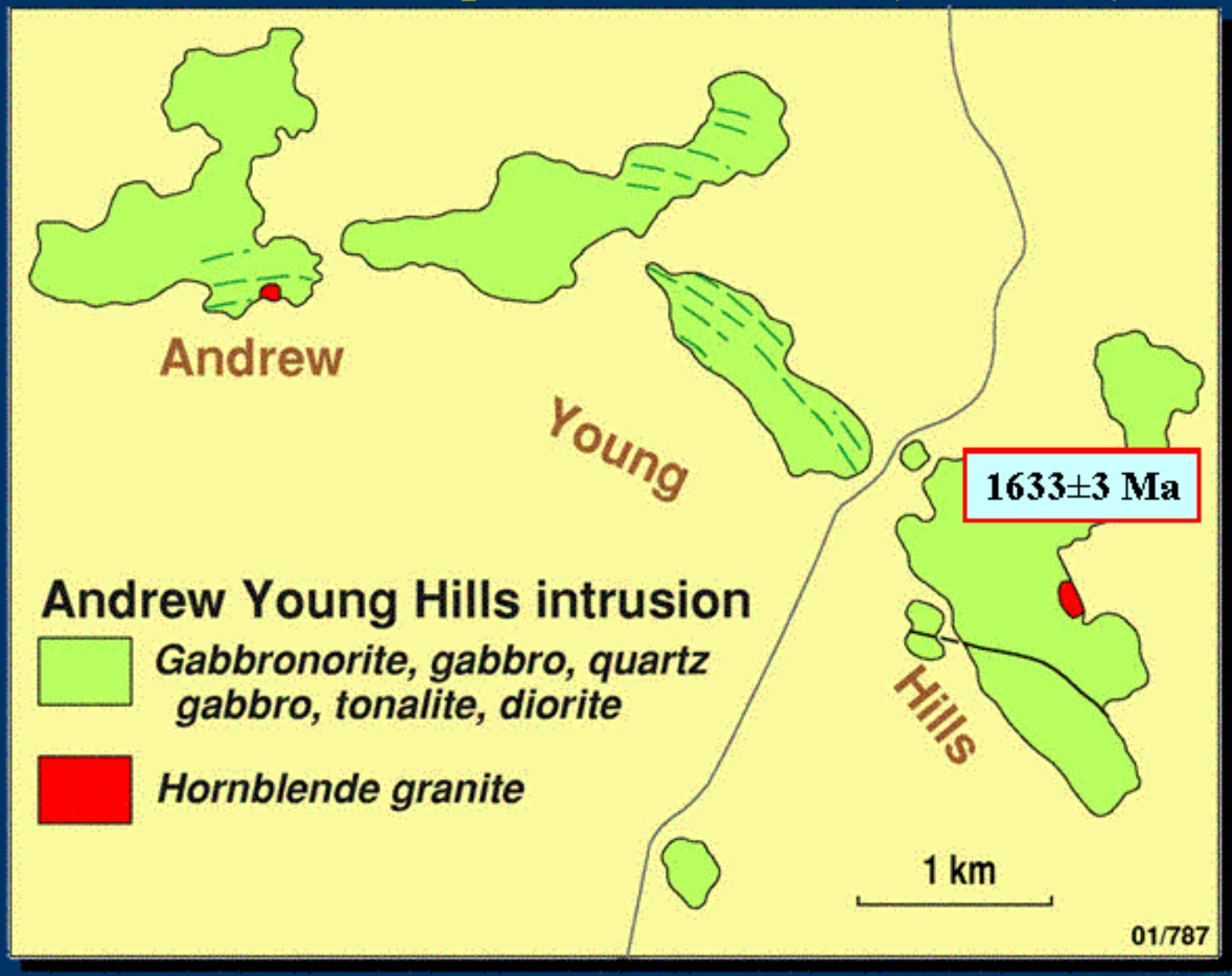
Massive Sulphides

	Nebo	Radio Hill	Voisey's Bay
Ni %	2.4	2.5	2.8
Cu %	1.8	1.8	1.7
Co %	0.1	0.1	0.1
Ni+Cu	4.2	4.3	4.5
Ni/Cu	1.3	1.4	1.6
Ni/Co	24	25	28

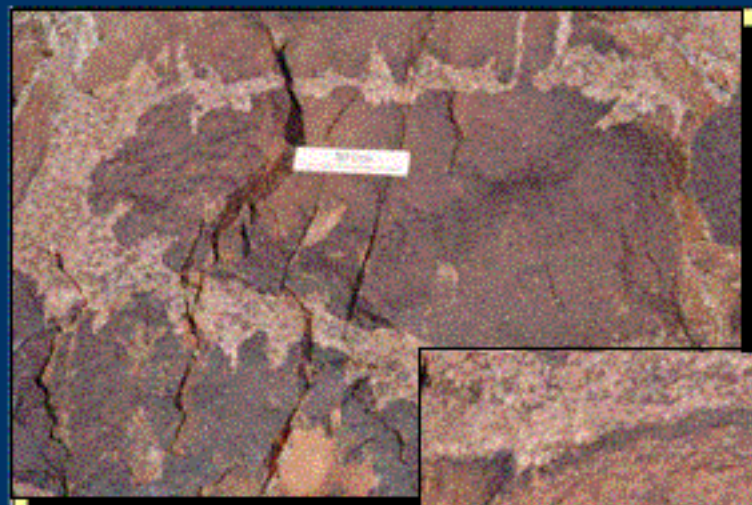
Proterozoic Mafic-Ultramafic Intrusions: Arunta Block

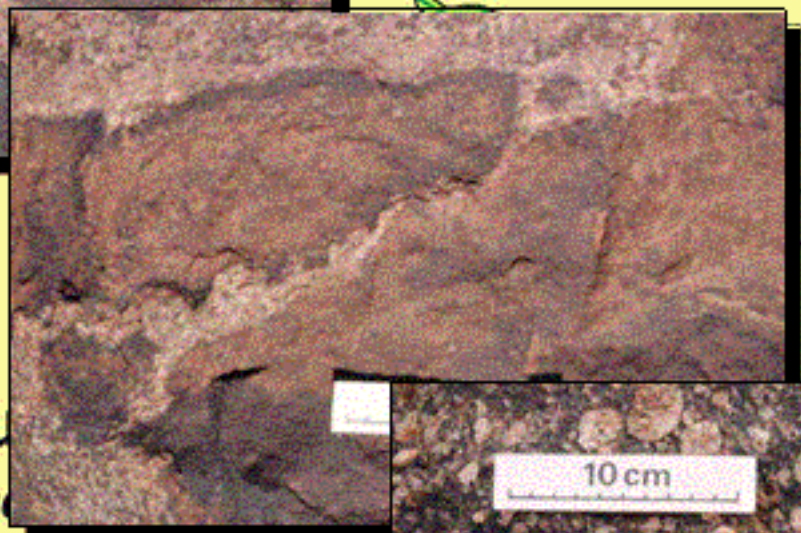


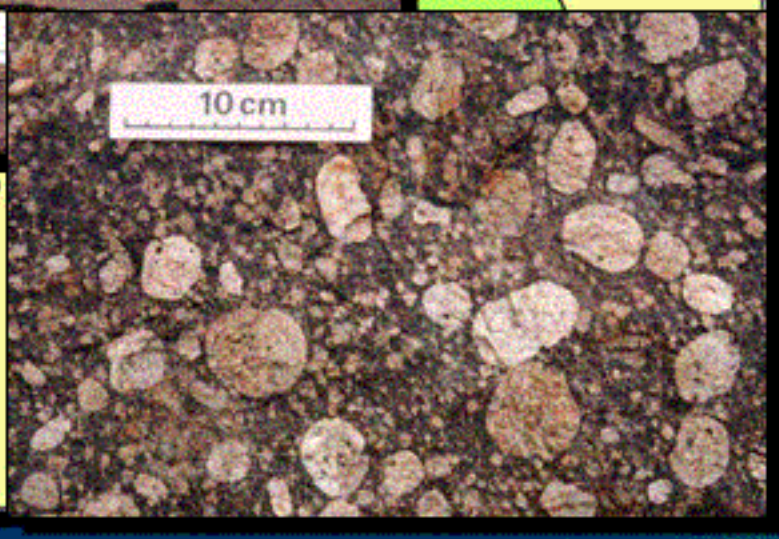
Andrew Young Hills Intrusion (1635 Ma)

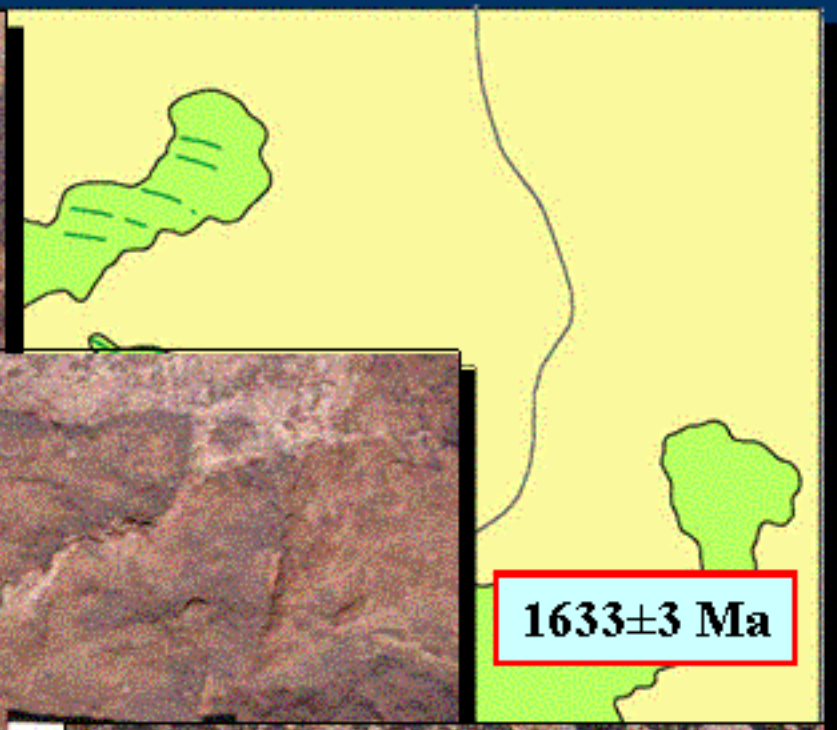


Andrew Young Hills Intrusion (1635 Ma)







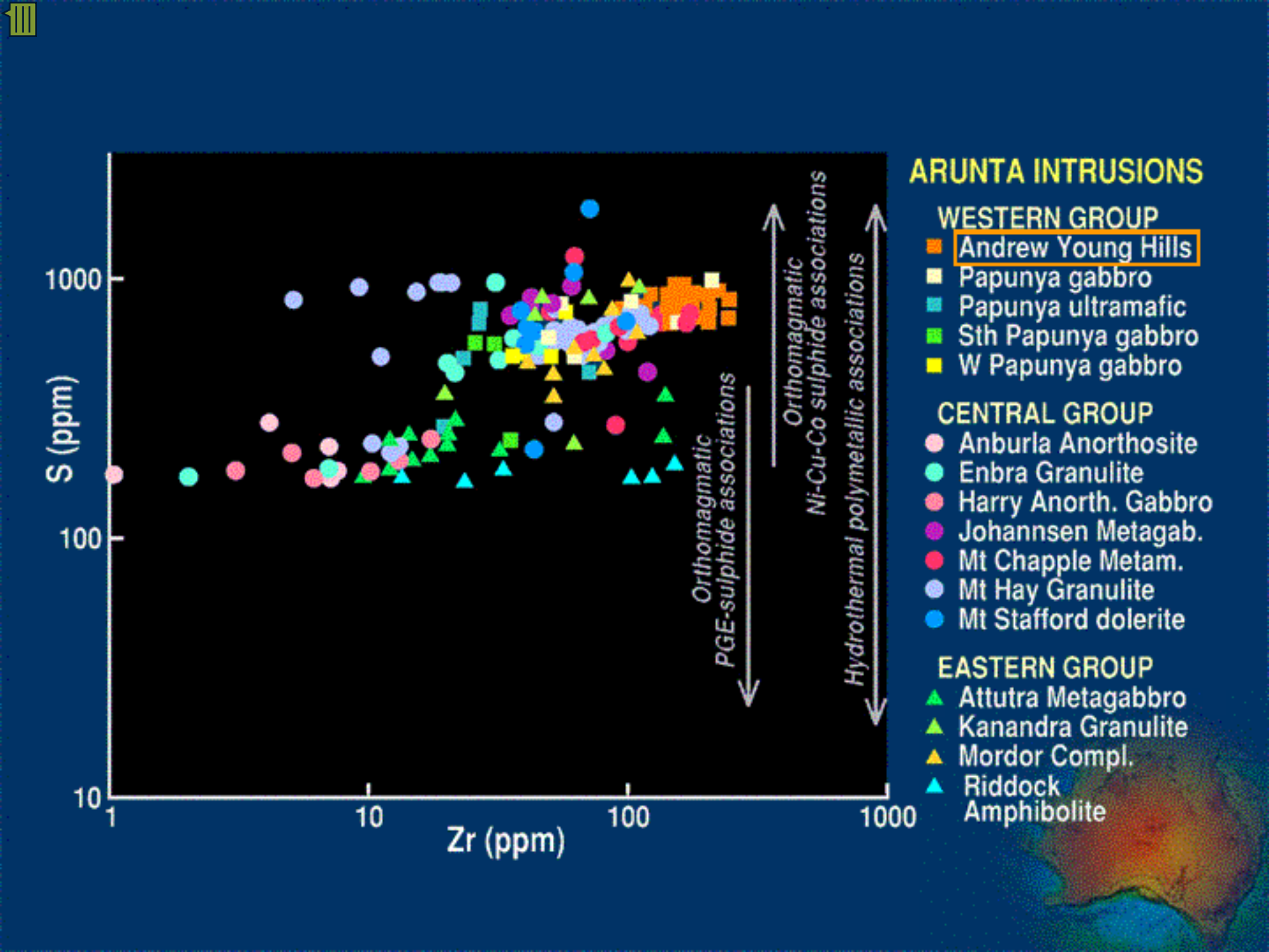


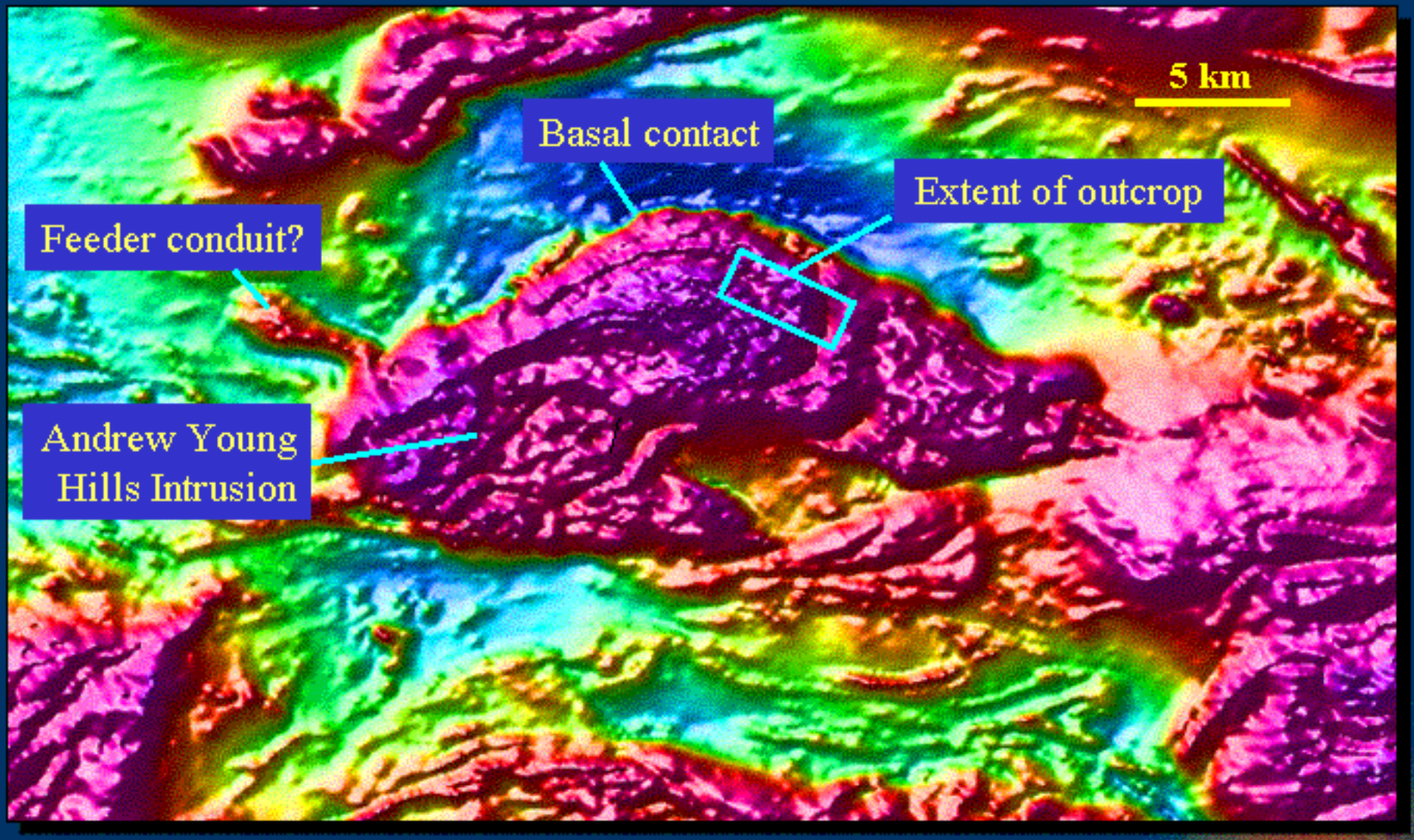
Andrew You

Gabbron

gabbro, tonalite, diorite

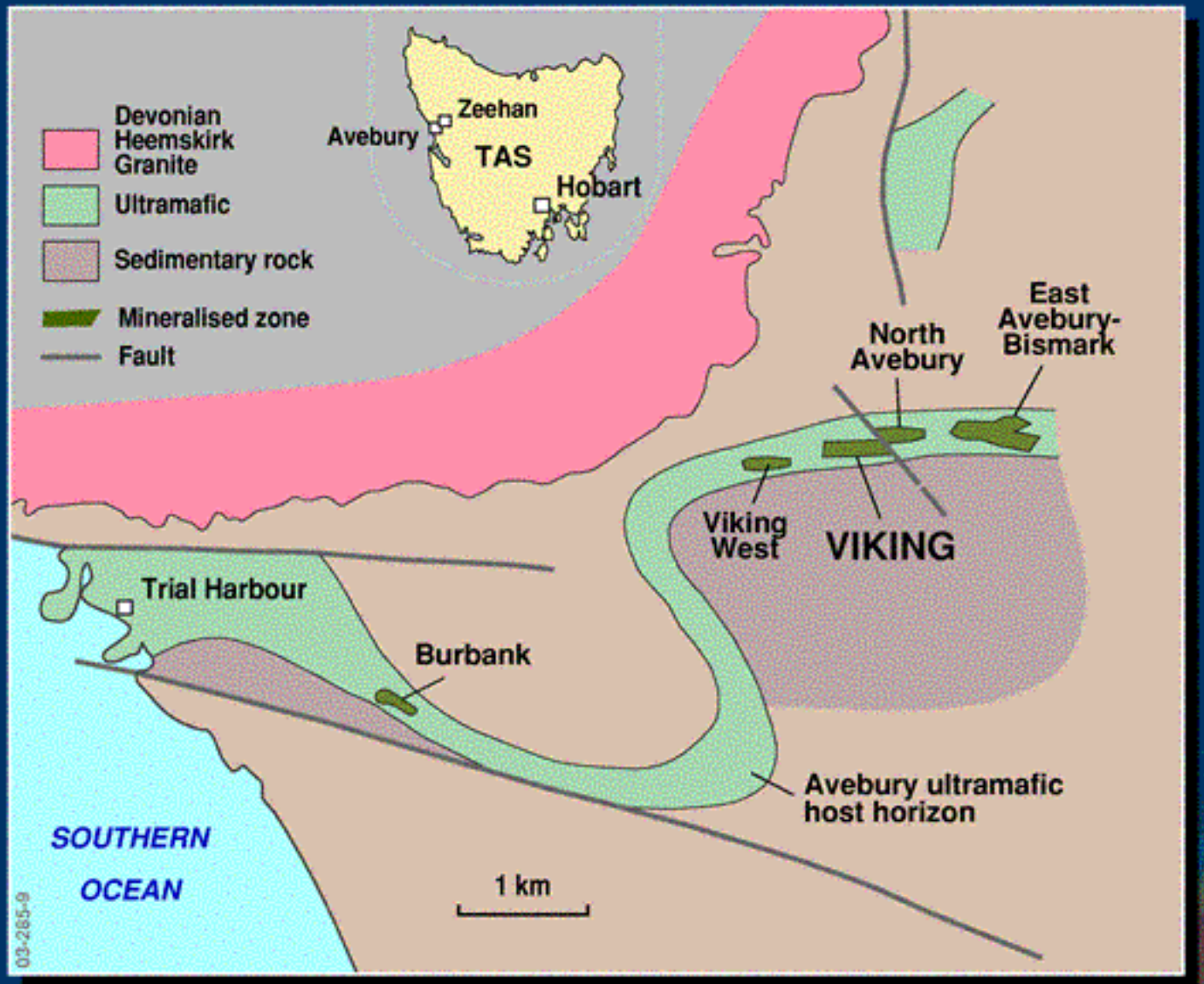
Hornblende granite


ARUNTA INTRUSIONS
WESTERN GROUP
Andrew Young Hills
Papunya gabbro
Papunya ultramafic
Sth Papunya gabbro
W Papunya gabbro
CENTRAL GROUP
Anburla Anorthosite
Enbra Granulite
Harry Anorth. Gabbro
Johannsen Metagab.
Mt Chapple Metam.
Mt Hay Granulite
Mt Stafford dolerite
EASTERN GROUP
Attutra Metagabbro
Kanandra Granulite
Mordor Compl.
Riddock Amphibolite
Orthomagmatic PGE-sulphide associations
Orthomagmatic Ni-Cu-Co sulphide associations
Hydrothermal polymetallic associations
S (ppm)
1000
100
10
1
10
100
1000
Zr (ppm)

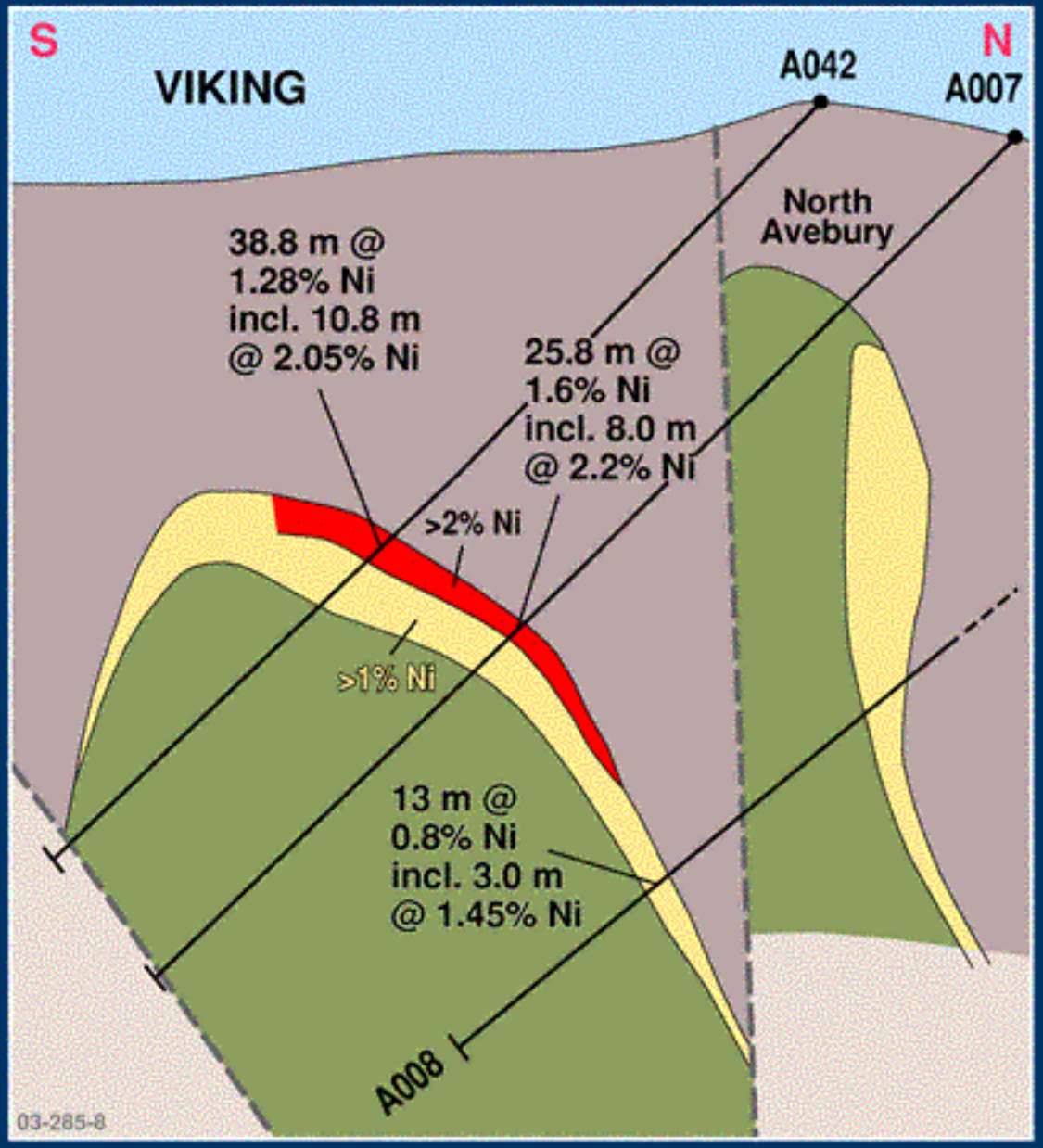


Total Magnetic Intensity (RTP)

Avebury (Late Devonian): Western Tasmania



Modified from: Allegiance Mining NL 2002 Annual Report



- Unusual Late Devonian ?skarn-hydrothermal deposit
- Ni remobilised by granite & redeposited in trap sites of altered ultramafic body
- Coarse pent-mt; S-poor, Fe-rich system
- 4 Mt @ 1.5% Ni

Serpentinite

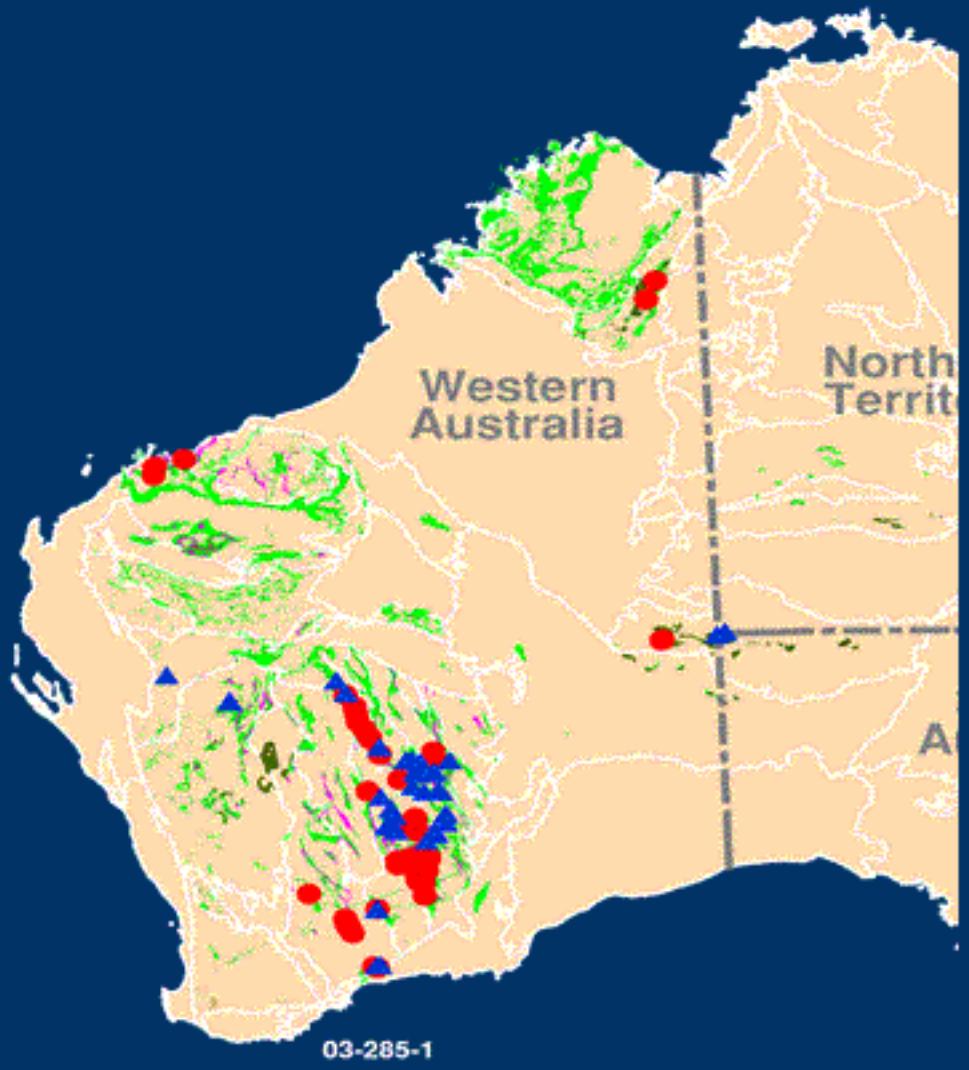
Sedimentary rock

Fault

100 m

Modified from: Allegiance Mining NL 2002 Annual Report

Recent Exploration Hotspots & Potential



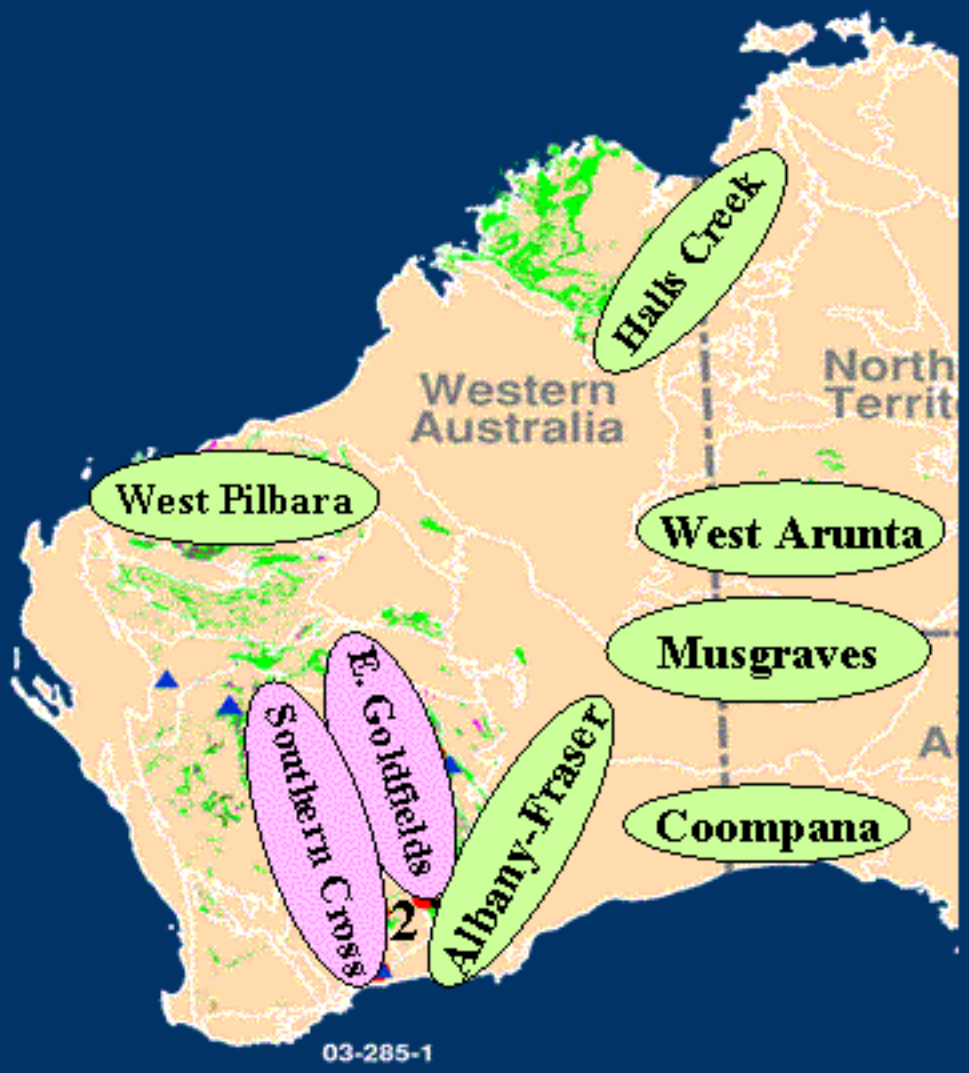
Komatiites

1 Flying Fox (21 m @ 7.8% Ni)
2 Maggie Hays (12 Mt @ 1.5% Ni)
3 Victor South (15 m @ 10% Ni)
4 McEwen (6 m @ 3% Ni)
5 Black Swan (9 Mt @ 2% Ni)
Others: Acra, Blair, Beta Hunt, Gunbarrel, Miitel, Zabel, Zone 29

Mafic Intrusions

6 Nebo (26 m @ 2.5% Ni, 1.8% Cu)
7 Radio Hill (25 m @ 3.2% Ni, 1.9% Cu)
8 Sally Malay (7m @ 1.6% Ni, .7% Cu)
9 Andrew Young Hills
10 Windimurra-Narndee

Recent Exploration Hotspots & Potential



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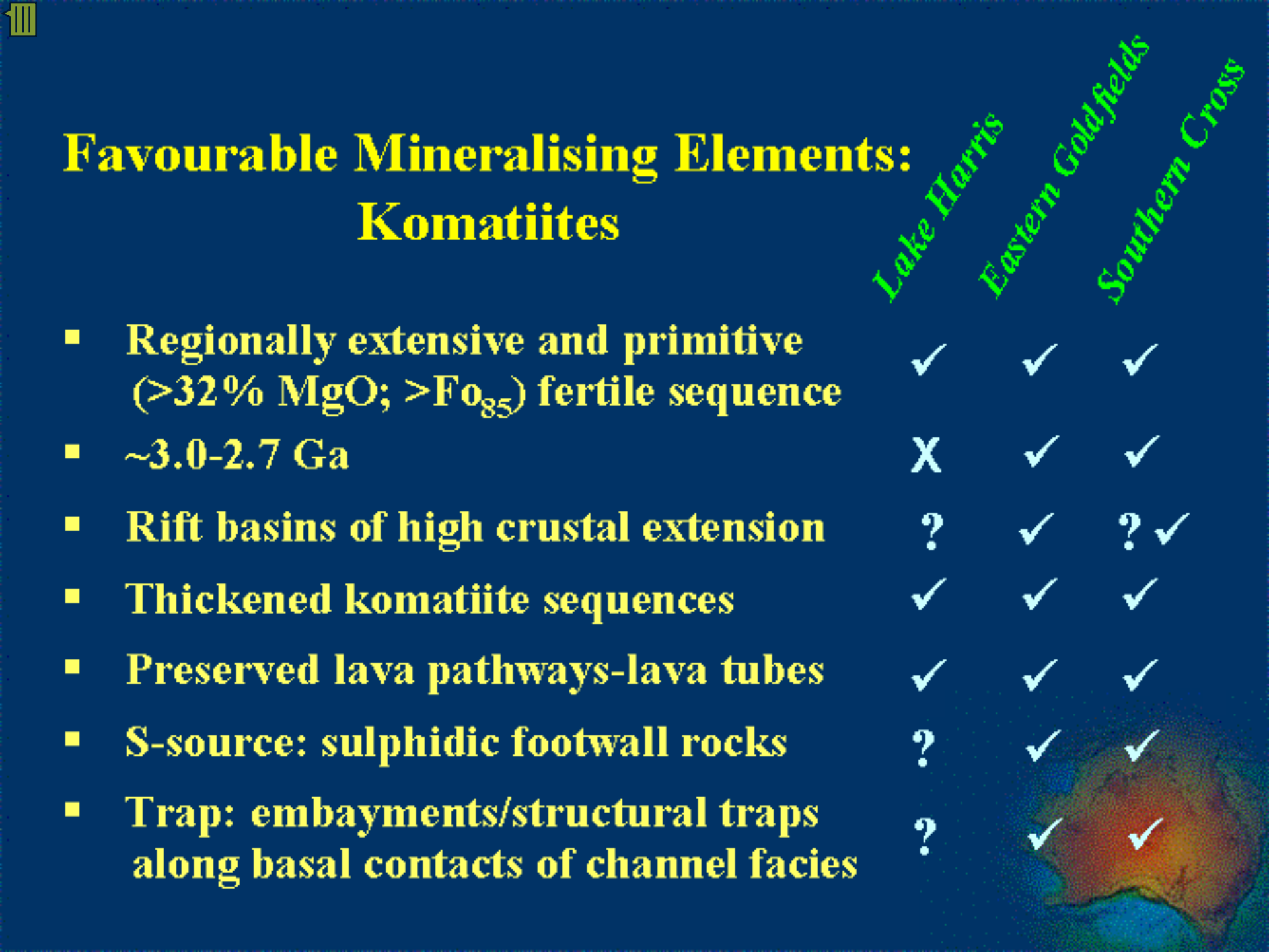
Favourable Mineralising Elements: Komatiites

	Lake Harris	Eastern Goldfields	Southern Cross
▪ Regionally extensive and primitive (>32% MgO; >Fo_{85}) fertile sequence	✓	✓	✓
▪ ~3.0-2.7 Ga	X	✓	✓
▪ Rift basins of high crustal extension	?	✓	? ✓
▪ Thickened komatiite sequences	✓	✓	✓
▪ Preserved lava pathways-lava tubes	✓	✓	✓
▪ S-source: sulphidic footwall rocks	?	✓	✓
▪ Trap: embayments/structural traps along basal contacts of channel facies	?	✓	✓



Favourable Mineralising Elements: Mafic Intrusions

	Musgrave	Halls Creek	Pilbara
▪ Small to medium, massive/layered mafic±ultramafic intrusions	✓	✓	✓
▪ Archaean to late Prot (3.0-1.1 Ga)	✓	✓	✓
▪ Proterozoic mobile zones or former rift zones of Archaean cratons	✓	✓	✓
▪ S saturation of magmas in conduit (by contamination) not depleted in Ni by ol	?	✓	✓
▪ Focussed magma flow-dynamic systems	?	✓	?
▪ Preserved feeder conduit/basal contact	✓	✓	✓

Visit Geoscience Australia's Booth

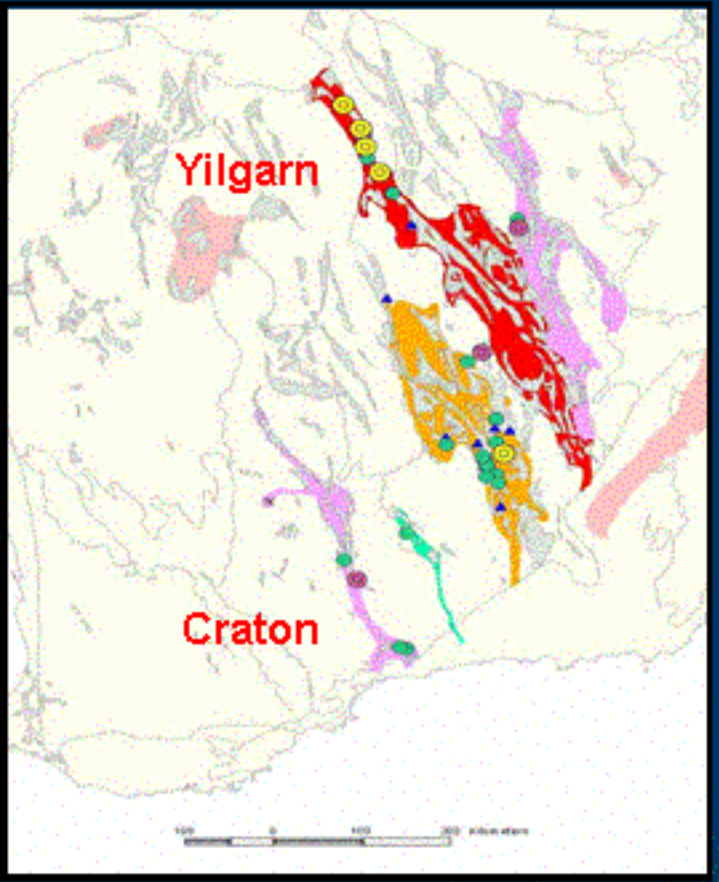
Nickel Sulphide Potential

GIS on Australia's Nickel Metallogenic Provinces based on:

- type of deposit
- similar age
- contiguity of geology

and

linked to GA's resource & geological databases



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