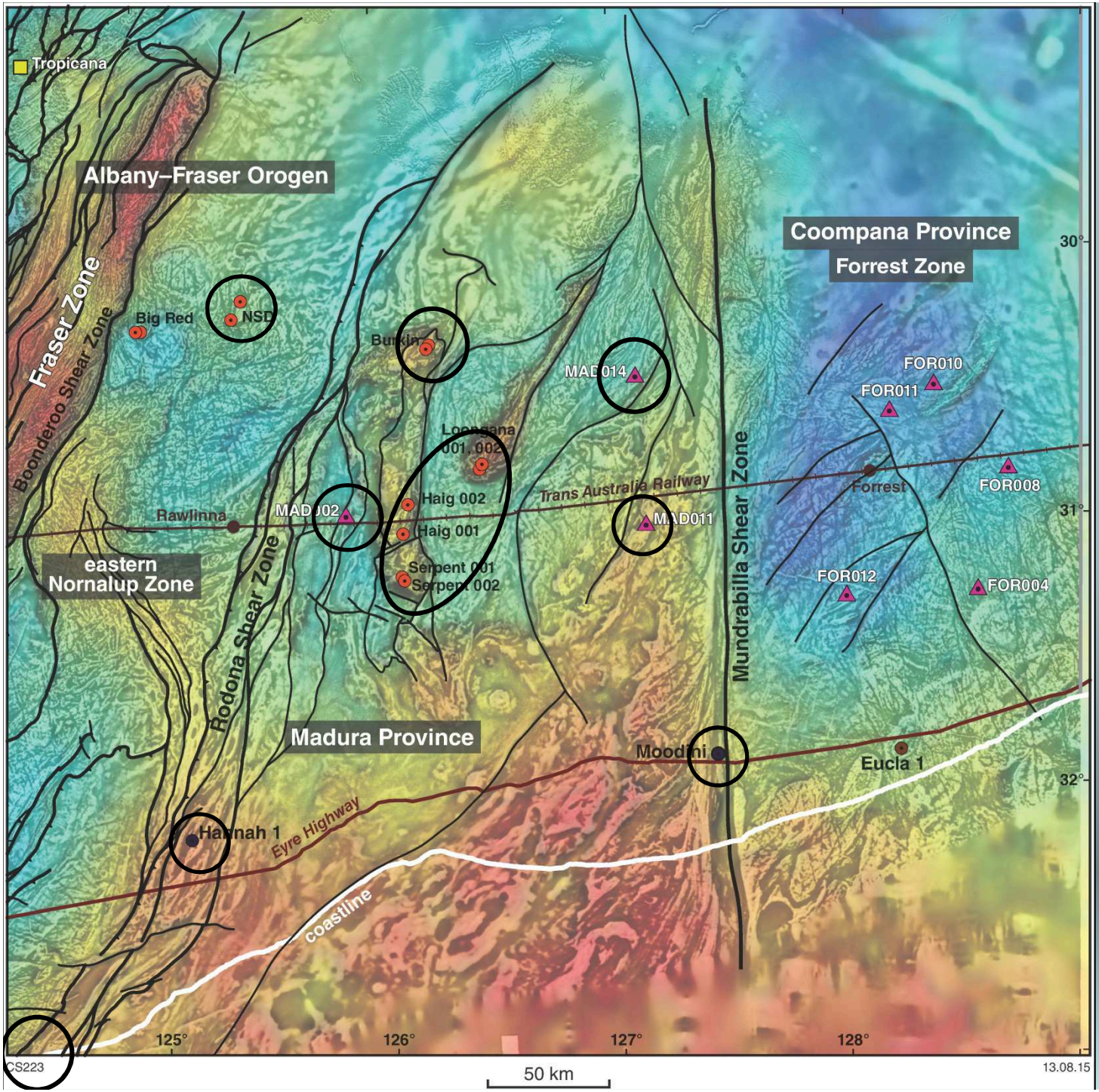
Eucla Basement Stratigraphic Drilling – Results Release

Madura Province: geochemistry and petrogenesis

Hugh Smithies, Catherine Spaggiari, Chris Kirkland, Michael Wingate, and Dick England

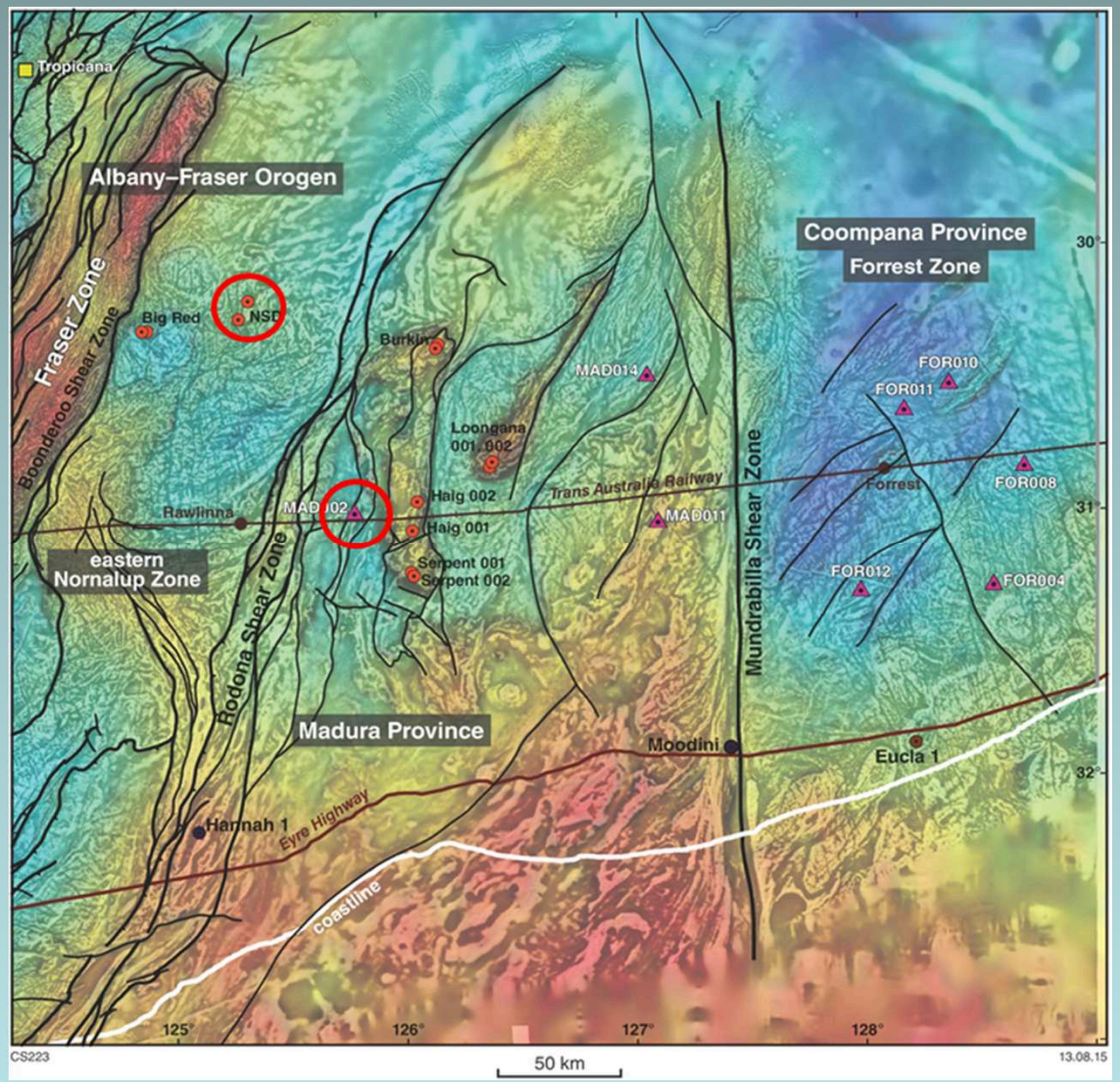
Preliminary

- Geochemical and Nd-isotopic characteristics and variations
- What we can infer in terms of petrogenesis
- Speculate on tectonic settings
- Cover some more regional aspects

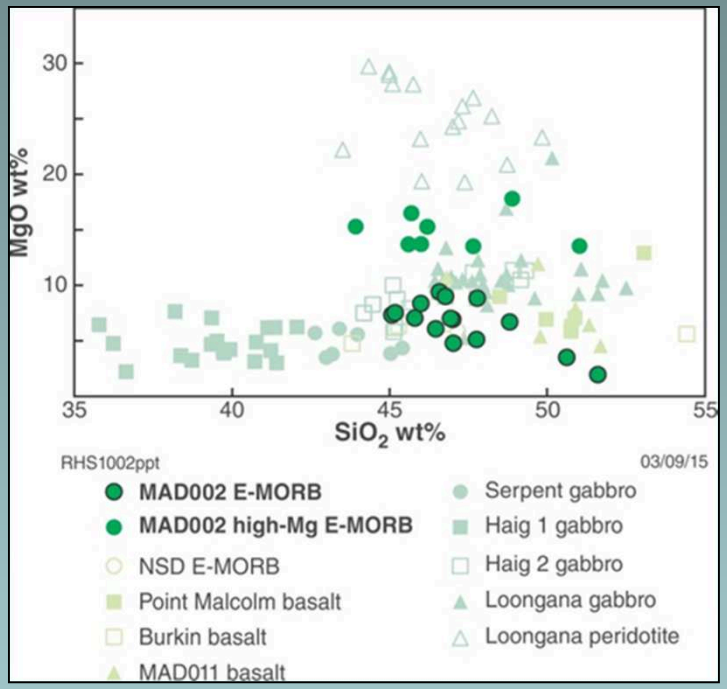

Tropicana
Albany–Fraser Orogen
Fraser Zone
Boonderoo Shear Zone
Big Red
NSD
Bunkin
MAD014
Coompana Province
Forrest Zone
FOR010
FOR011
Loongana 001, 002
Trans Australia Railway
Forrest
FOR008
Rawlinna
MAD002
Haig 002
Haig 001
MAD011
eastern Nornalup Zone
Serpent 001
Serpent 002
Rodona Shear Zone
Mundrabilla Shear Zone
FOR012
FOR004
Madura Province
Moodini
Eucla 1
Hannah 1
Eyre Highway
coastline
30°
31°
32°
125°
126°
127°
128°
50 km
CS223
13.08.15

Madura Province > 1400 Ma

E-MORB (undated but likely the oldest material sampled)



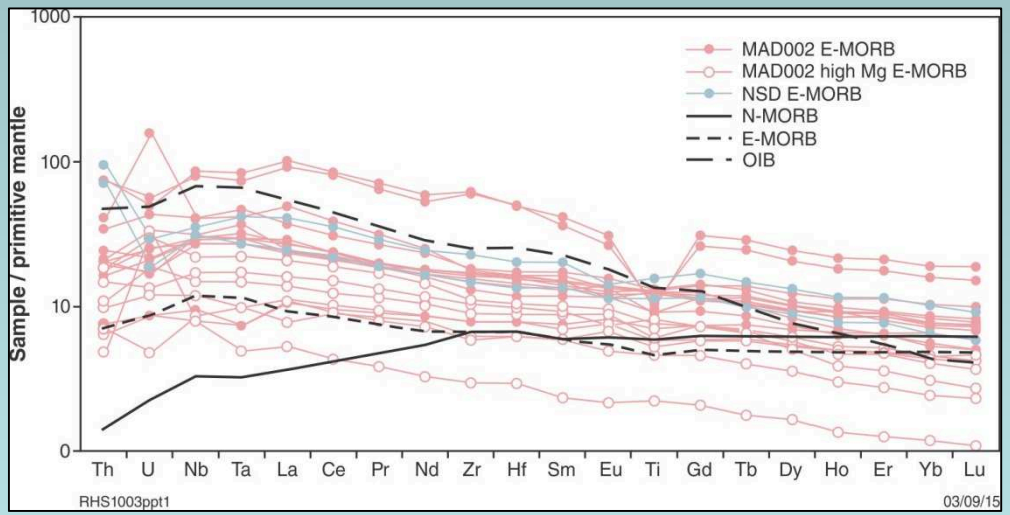
MAD002
NSD



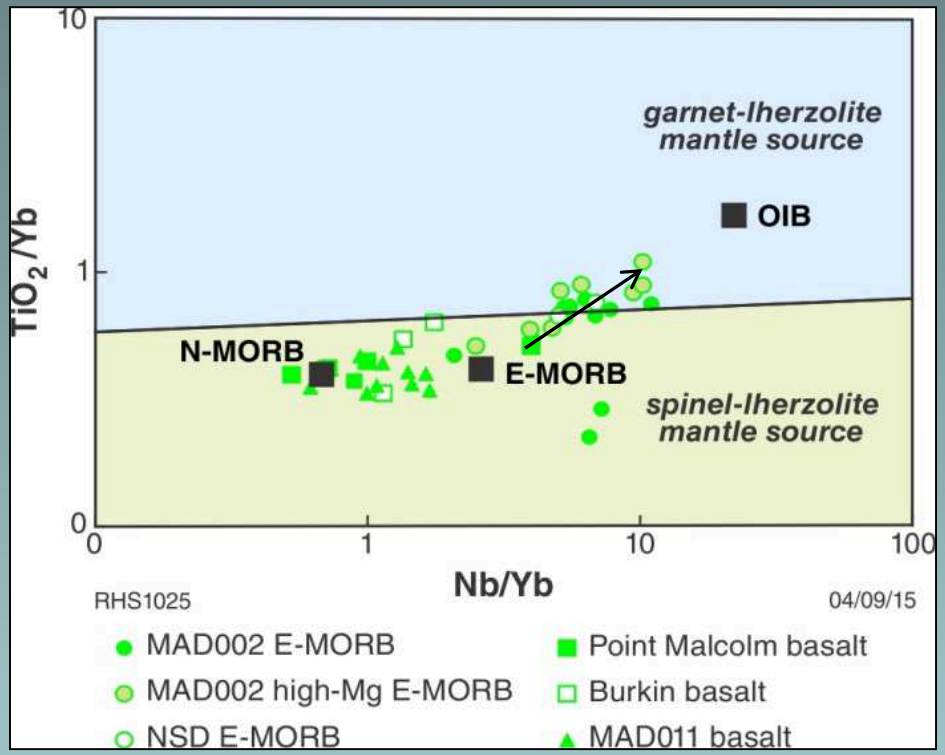
Possibly effusive

MgO up to 17.81 wt%; Mg# up to 75;
Cr up to 2520 ppm; Ni up to 1430 ppm.

These include near-primary mantle melts (although parallel trace element pattern suggest high MgO is at least partly due to cumulate olivine).



Normalized trace element patterns are strongly enriched but show no evidence of a 'crustal' component. These are transitional between E-MORB (enriched MORB) and OIB (ocean-island basalt).



These represent partial melts of a relatively undepleted mantle source.

High Ti/Yb ratios suggest deep melting (>100 km) where garnet preferentially sequesters HREE.

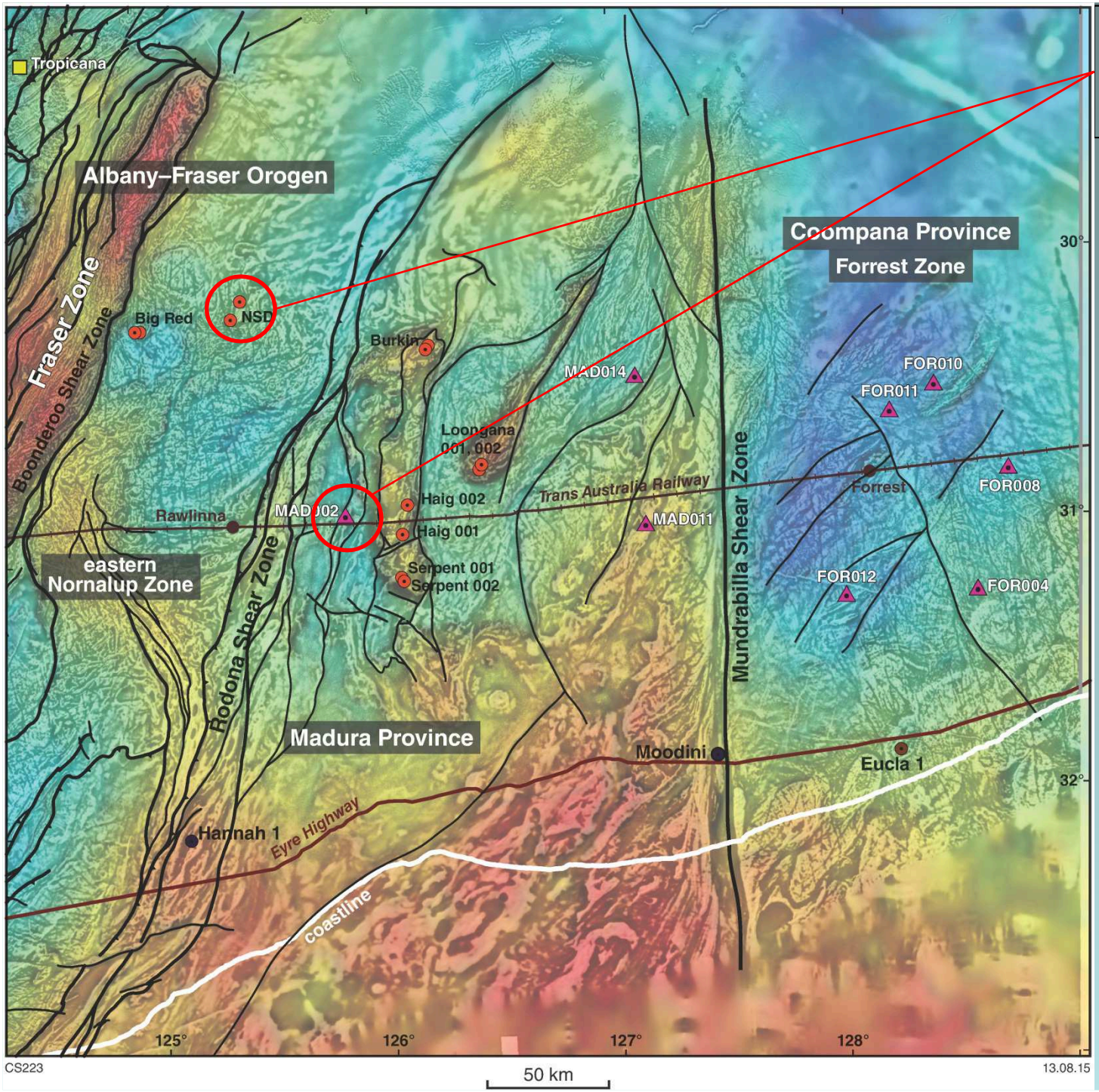
Reflects asthenospheric upwelling (? plume, oceanic plateau, continental rift → OCT, back-arc rift).

Age

Has to be older than c. 1389 Ma (age of intrusive granite)

Since they contain no crustal Sm-Nd, Nd-isotopic compositions (ε_{Nd} at 1400 Ma = +1.4 – +2.5) suggest an age >>1400 Ma

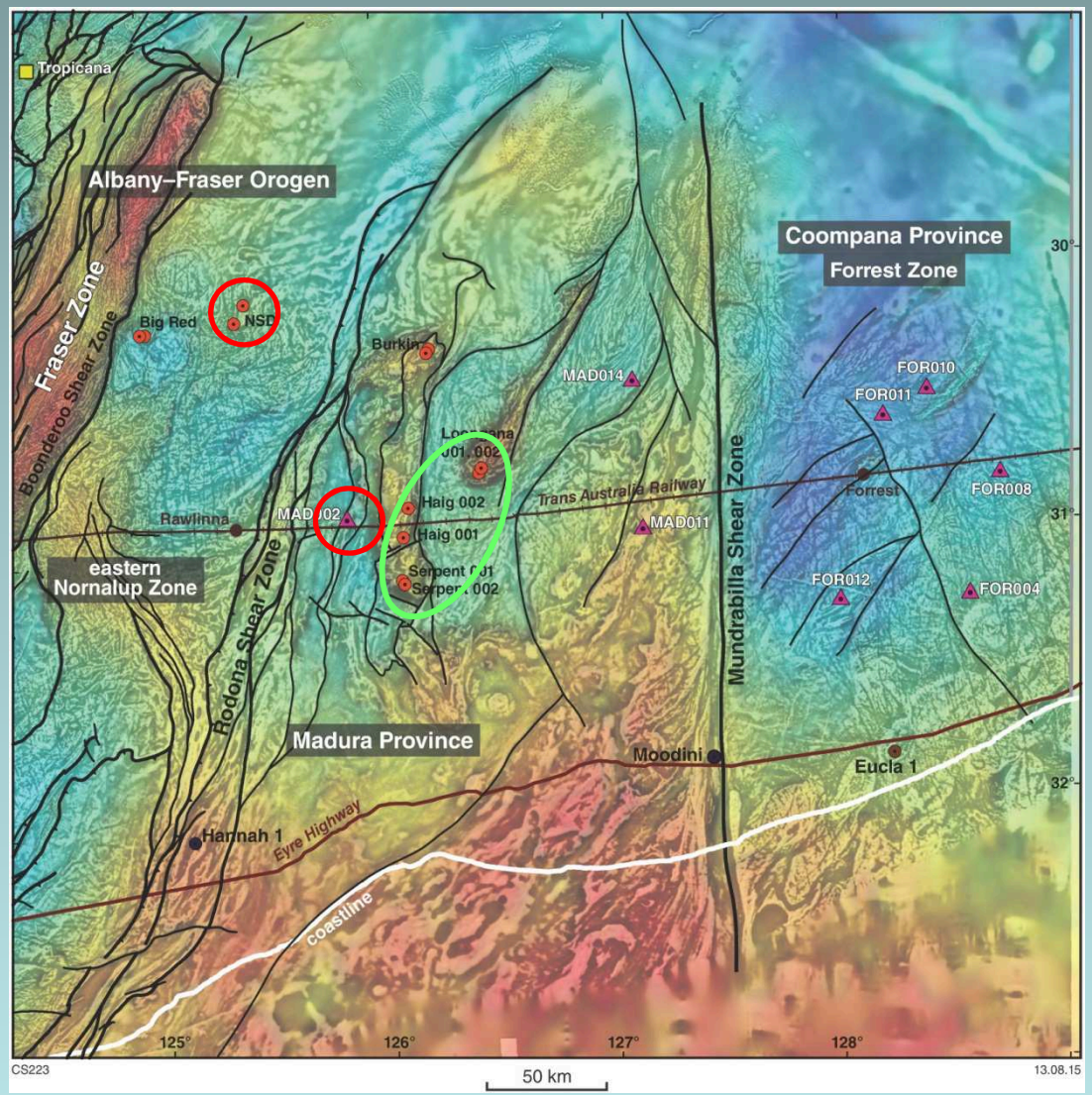
Modal ages suggest 1950 Ma or younger



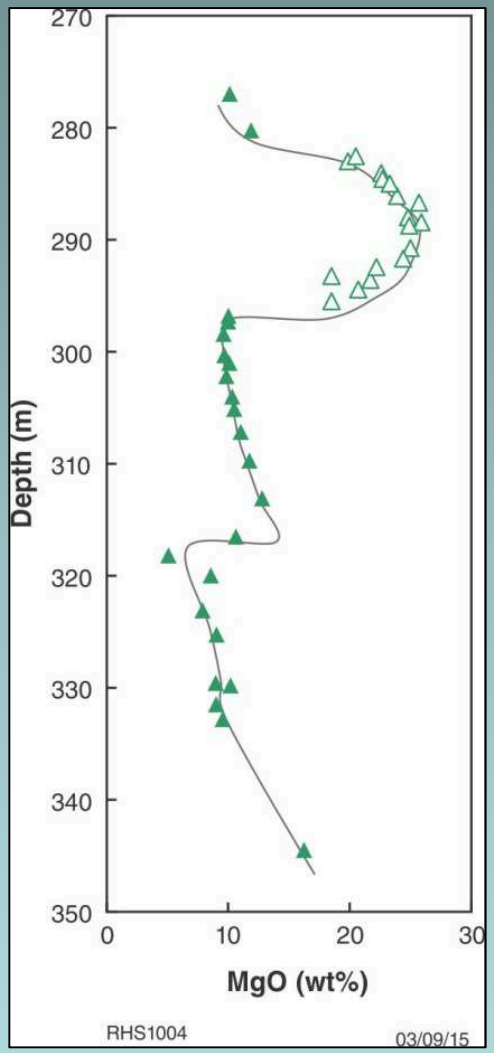
E-MORB/OIB
>> c. 1400 < 1950 Ma
Continental rifting?

Madura Province c. 1400 Ma

Mafic – ultramafic intrusions; the Loongana oceanic arc

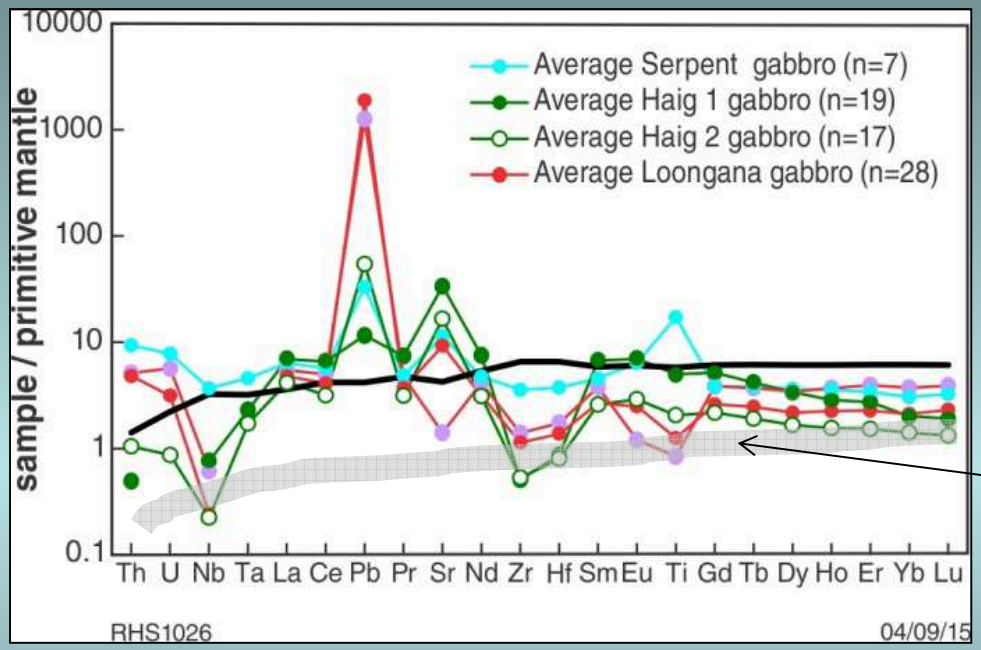


Loongana
Haig
Serpent



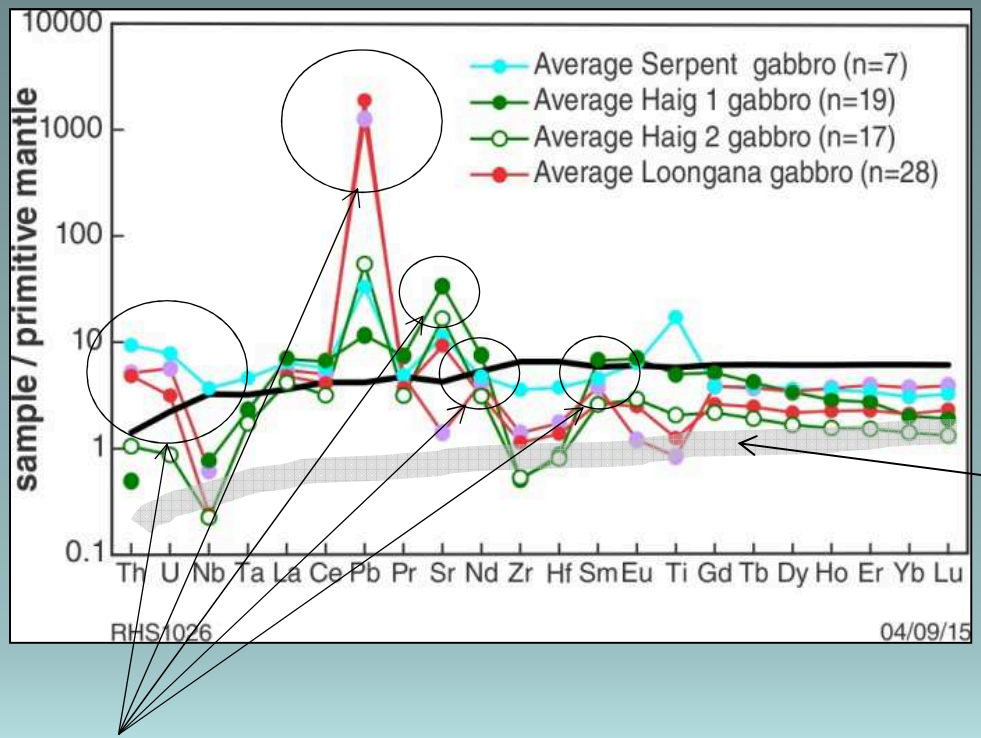
Gabbroic cumulates dominate but a significant thickness of peridotitic cumulate is found at Loongana

Haig includes clinopyroxene-rich gabbro (Haig 1) and hornblende-gabbro (Haig 2)



All form from broadly low-K tholeiitic parents but they have some clear compositional differences – mainly attributable to slightly different cumulate mineralogies.

Trends in HFSE (Nb, Zr, Ti) and Yb broadly parallel N-MORB and reflect a similarly depleted mantle source (N-MORB source)



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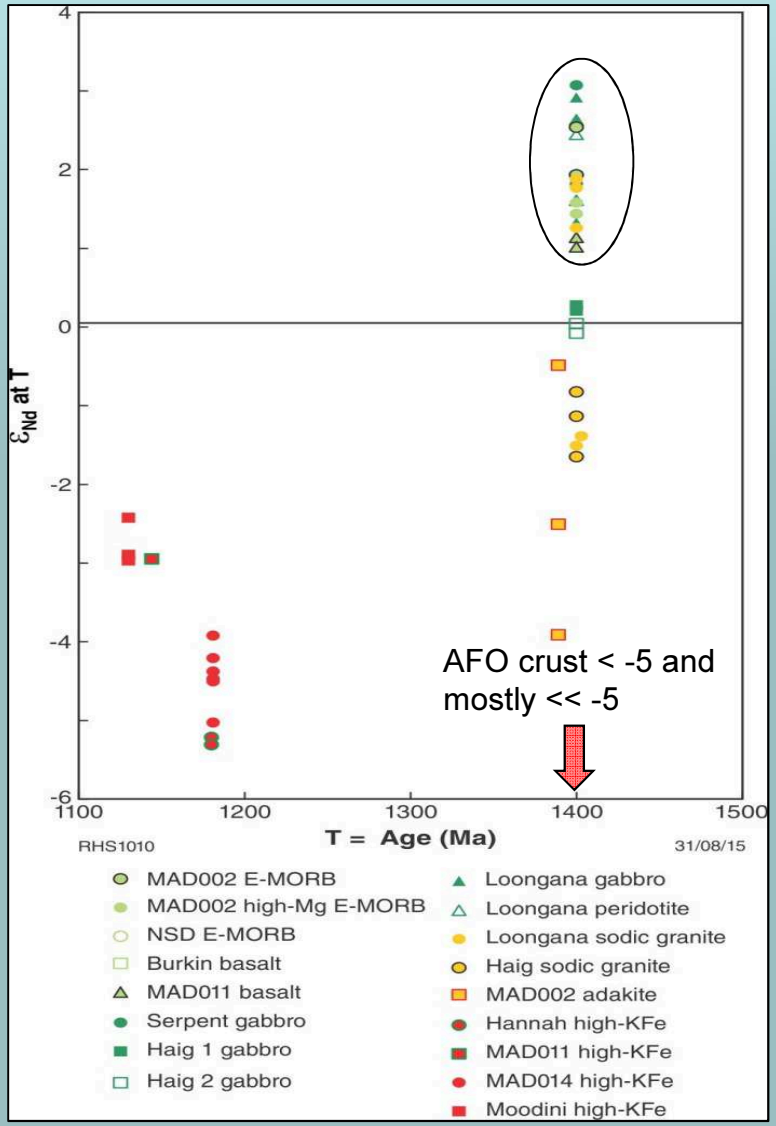
Enrichments in fluid- and melt-mobile incompatible trace elements reflect some sort of “crustal” contribution. Generally regarded as a ‘subduction signature’, realistically, geochemistry ***alone*** does not normally allow us to easily distinguish between mixing crustal into a mantle source region (i.e. subduction) and mixing crust into a mantle-derived melt

What we can say

- From a local and regional perspective – these are the most primitive rocks



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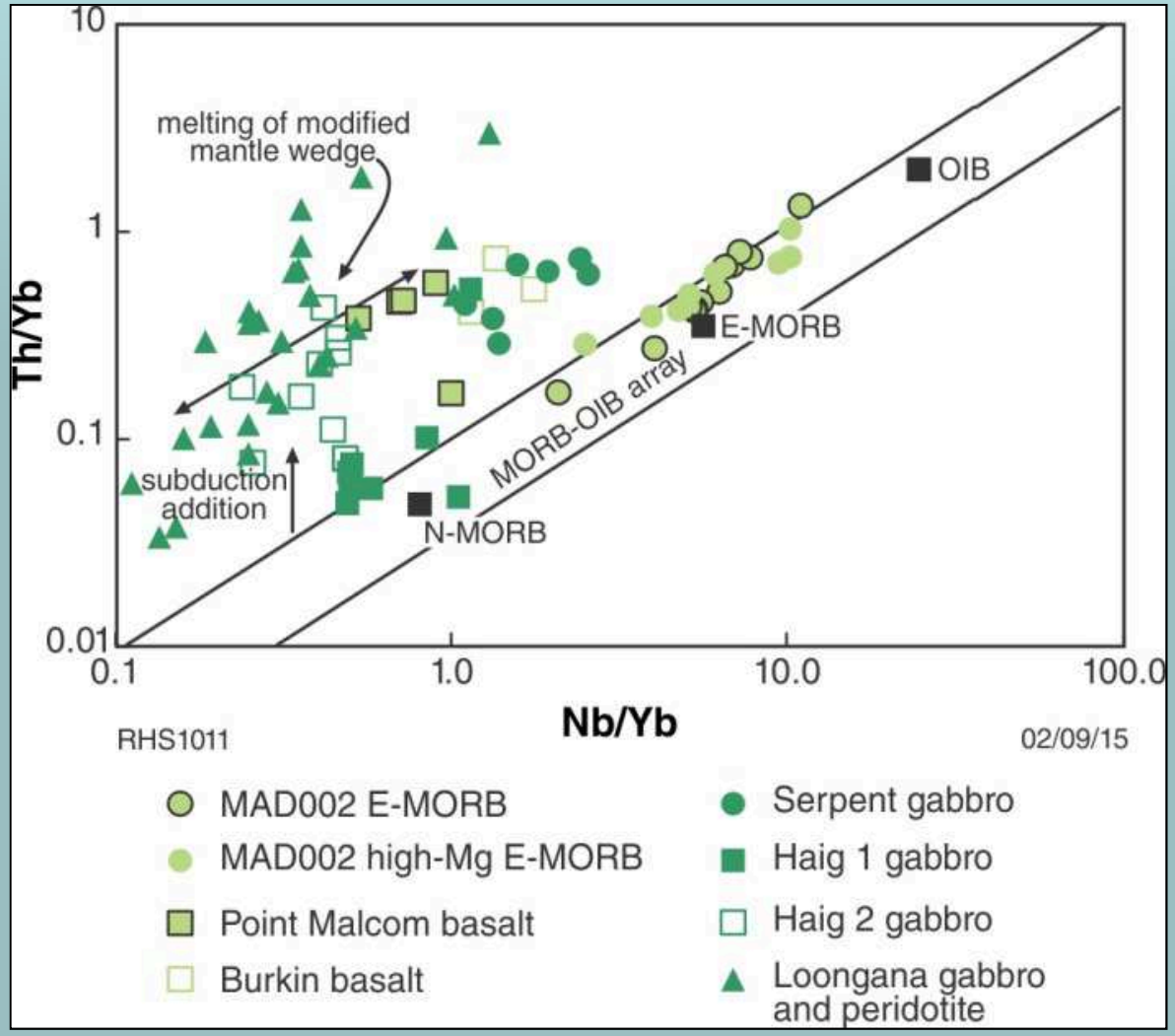
- From a local and regional perspective – these are the most primitive rocks
- On a Th/Yb vs Nb/Yb diagram (Pearce et al) they form part of a classic mantle-wedge melting array



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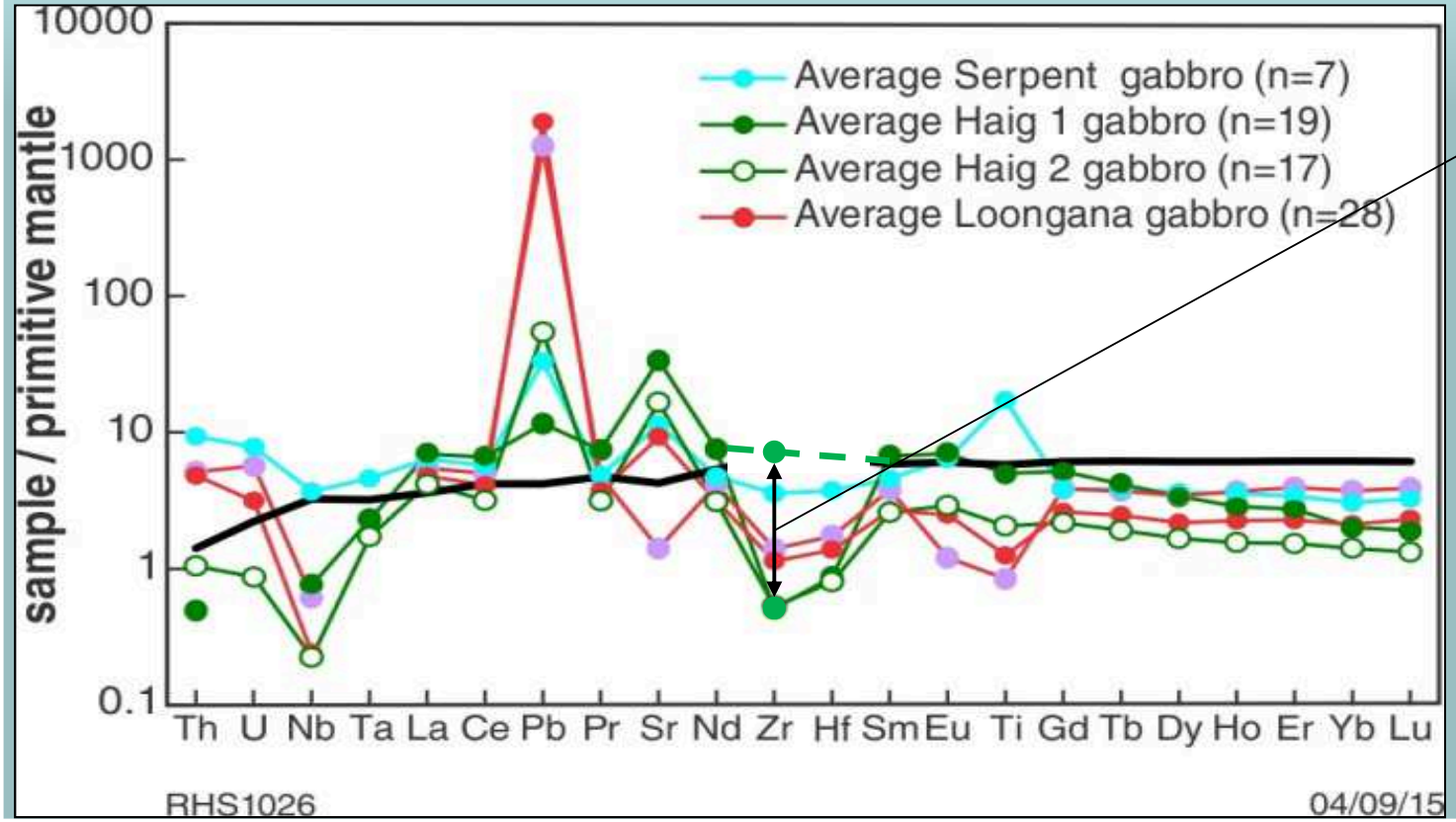
- All of the mafic-ultramafic intrusions show prominent Zr anomalies – commonly attributed to processes operating in the mantle wedge.



Zr/Zr*

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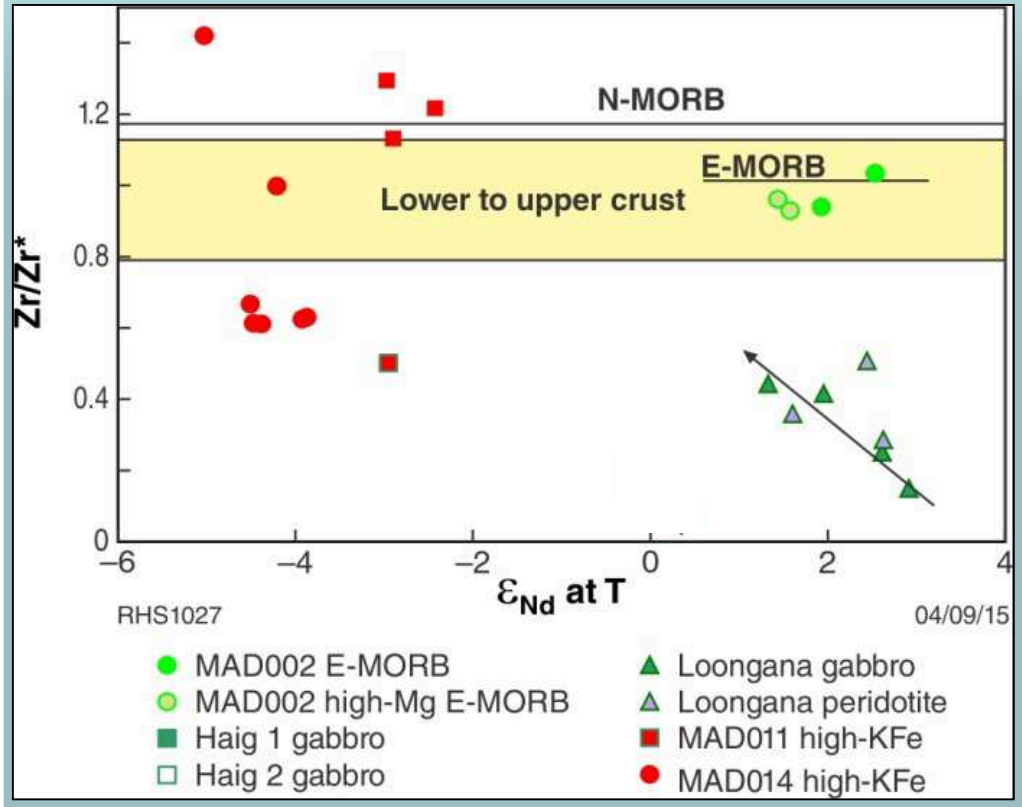

The Zr/Zr* anomalies originate from the more primitive (mantle) component – reflection of a modified source or unusual melting conditions

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- **Locally abundant sodic granites with ‘oceanic plagiogranite’ compositions**

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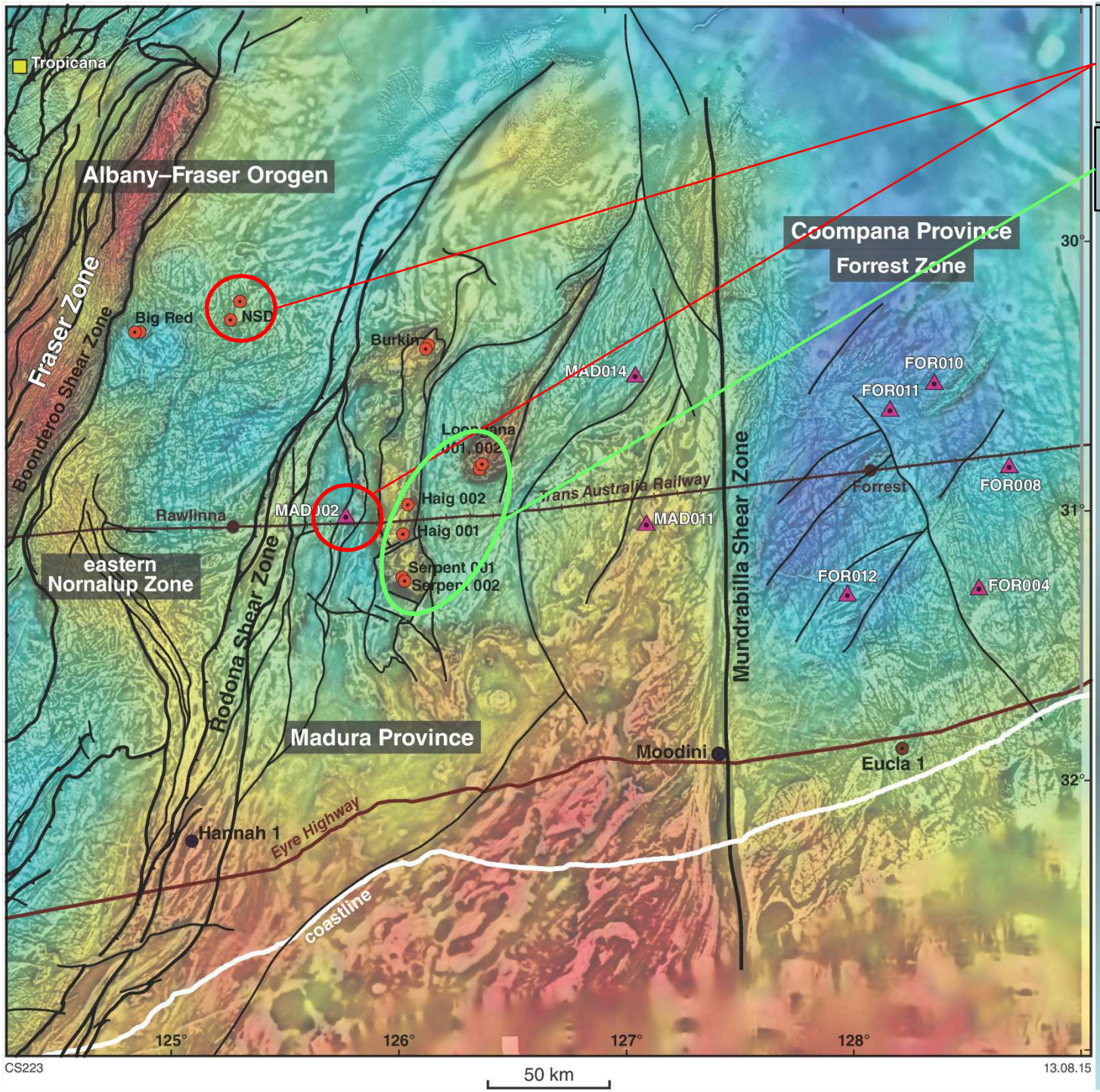
Our interpretation... Oceanic arc – the Loongana Arc

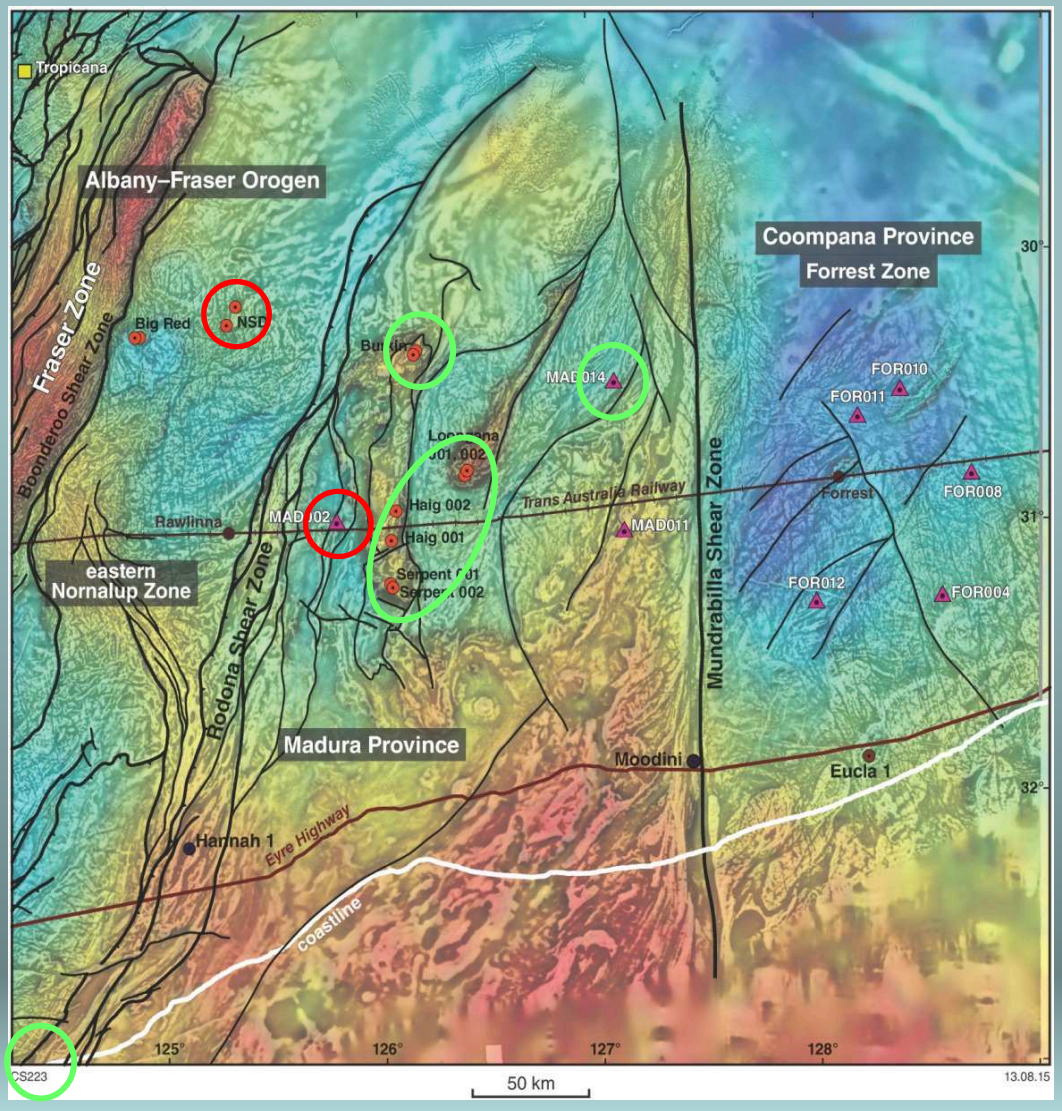


E-MORB/OIB
>> c. 1400 < 1950 Ma
Continental rifting?

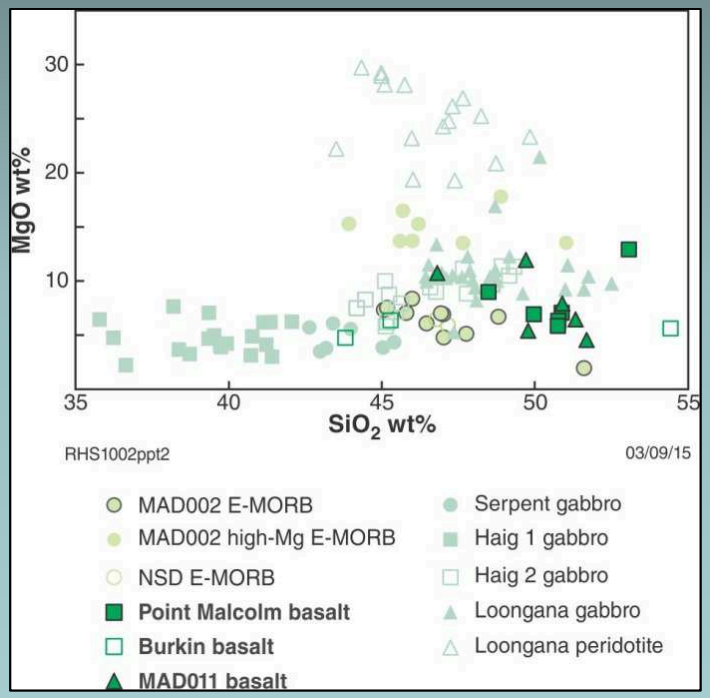
Subduction-modified N-MORB at c. 1400 Ma

Madura Province c. 1400 Ma

Subduction-modified N-MORB: back- or fore-arc basalts

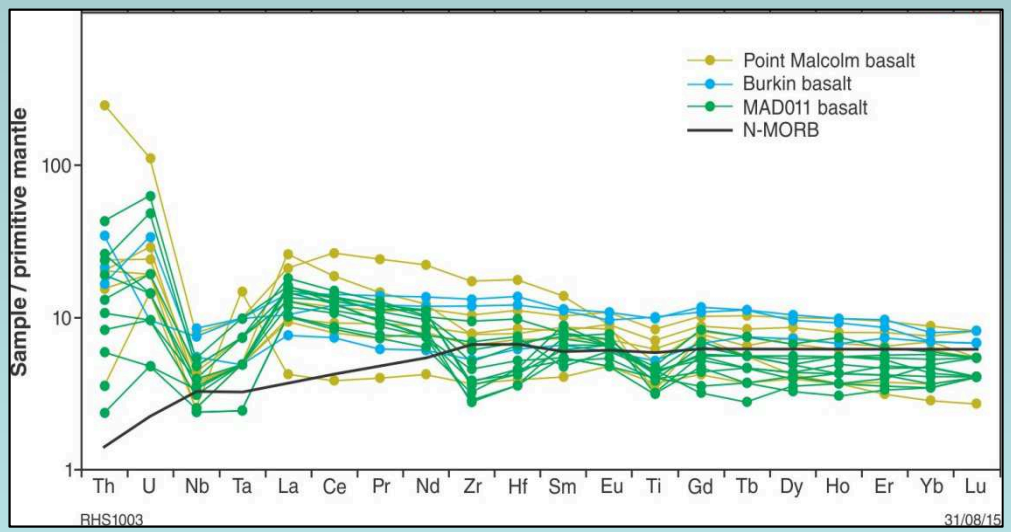


Burkin
Point Malcolm
MAD011

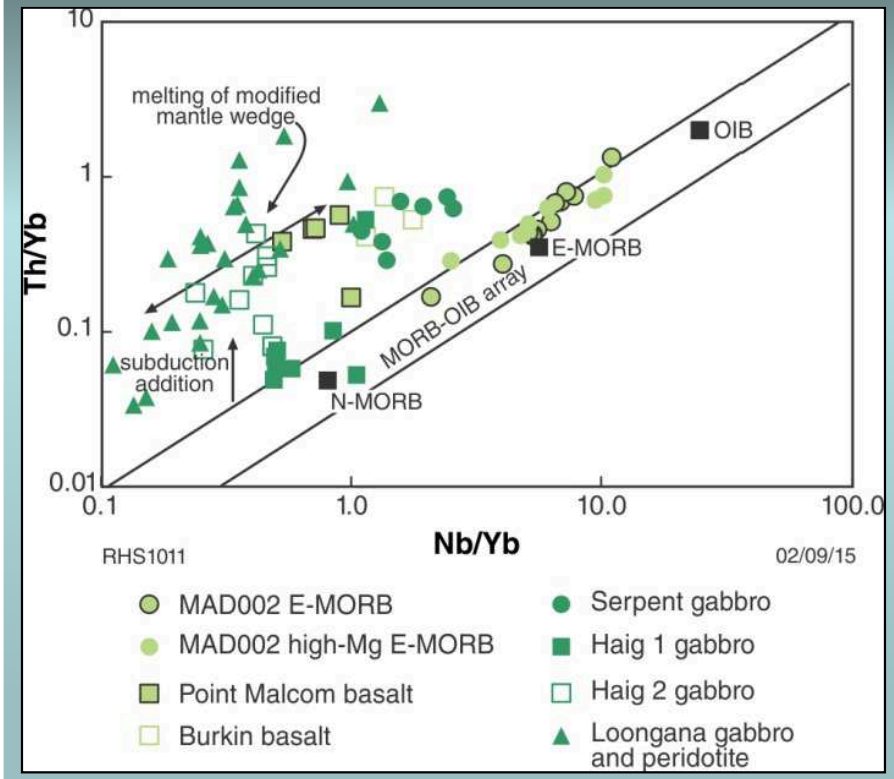


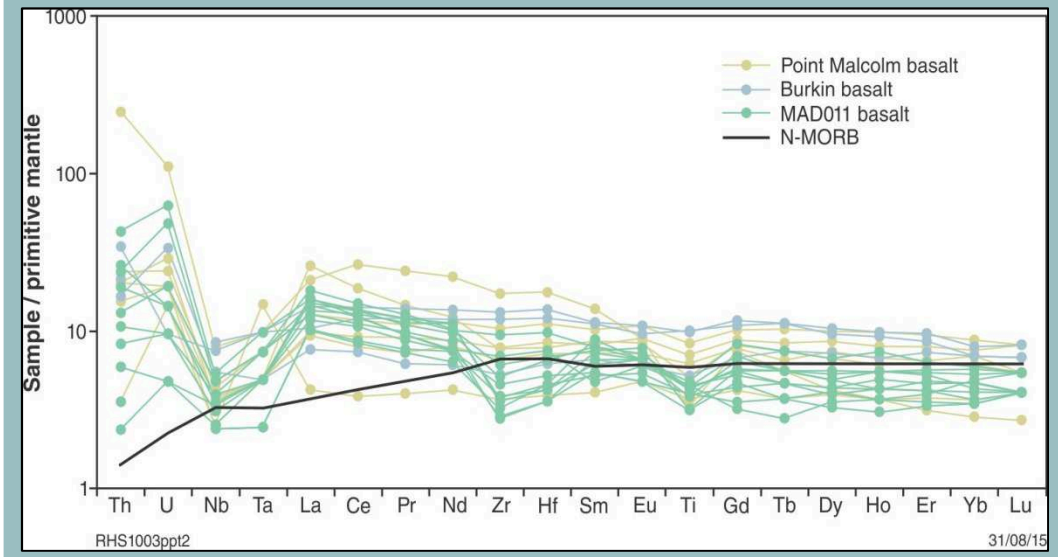
MgO up to ~ 10 wt% and Mg# up to 76 but mainly much lower.

Point Malcolm	Cr up to 1751 ppm Ni up to 279 ppm
MAD011	Cr up to 558 ppm Ni up to 157 ppm



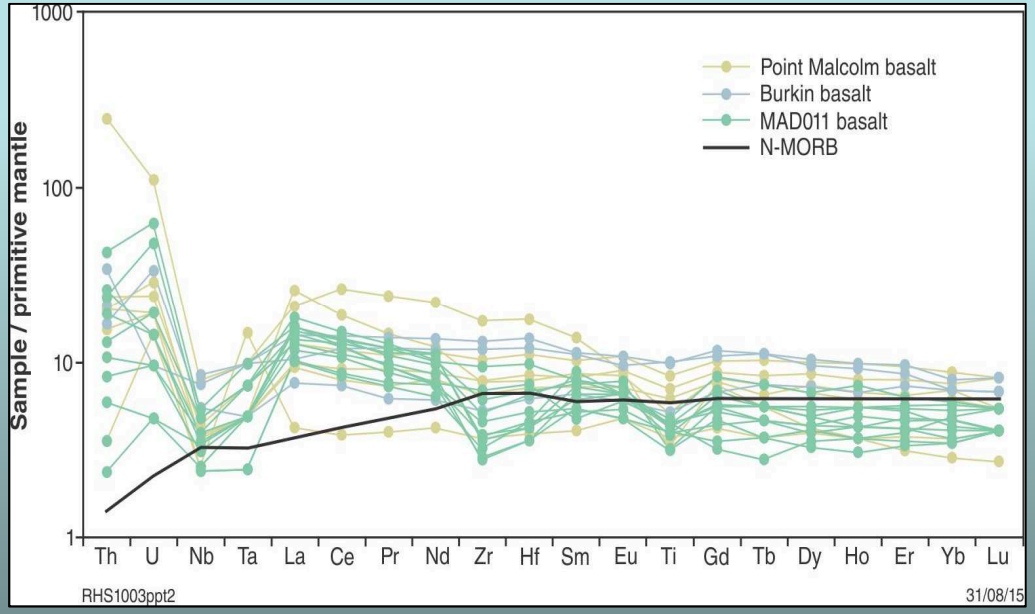
All have relatively flat normalized trace element patterns. Like the gabbros, trends for HFSE and Yb suggest a source very similar to N-MORB source – and again, we see enrichment patterns indicating interaction between an evolved component and N-MORB or between an evolved component and N-MORB source.





- Form part of an apparent mantle wedge melting array
- Appear to be related in space and time with mafic-ultramafic intrusions that we also suspect are subduction related

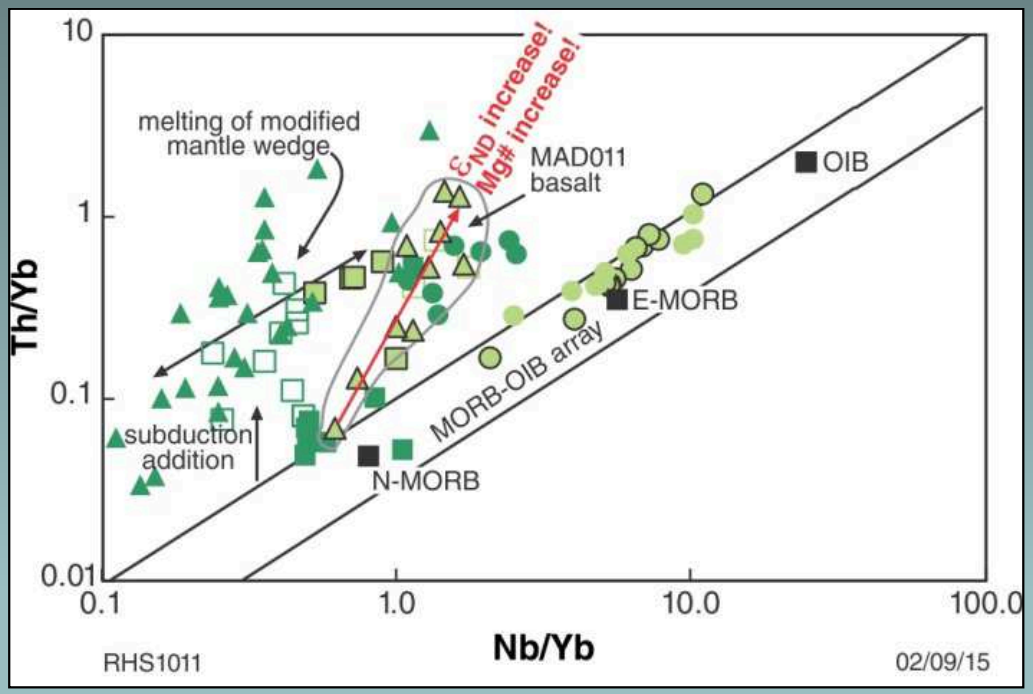
Enrichment patterns are relatively weak, pointing to fore-arc or back-arc tholeiites.



MAD011 basalts

These form rafts and xenoliths in c. 1135 Ma medium-grained mafic rocks but are compositionally and isotopically distinct (not co-genetic).

Have N-MORB like HFSE-Yb patterns, including prominent negative Zr-anomalies



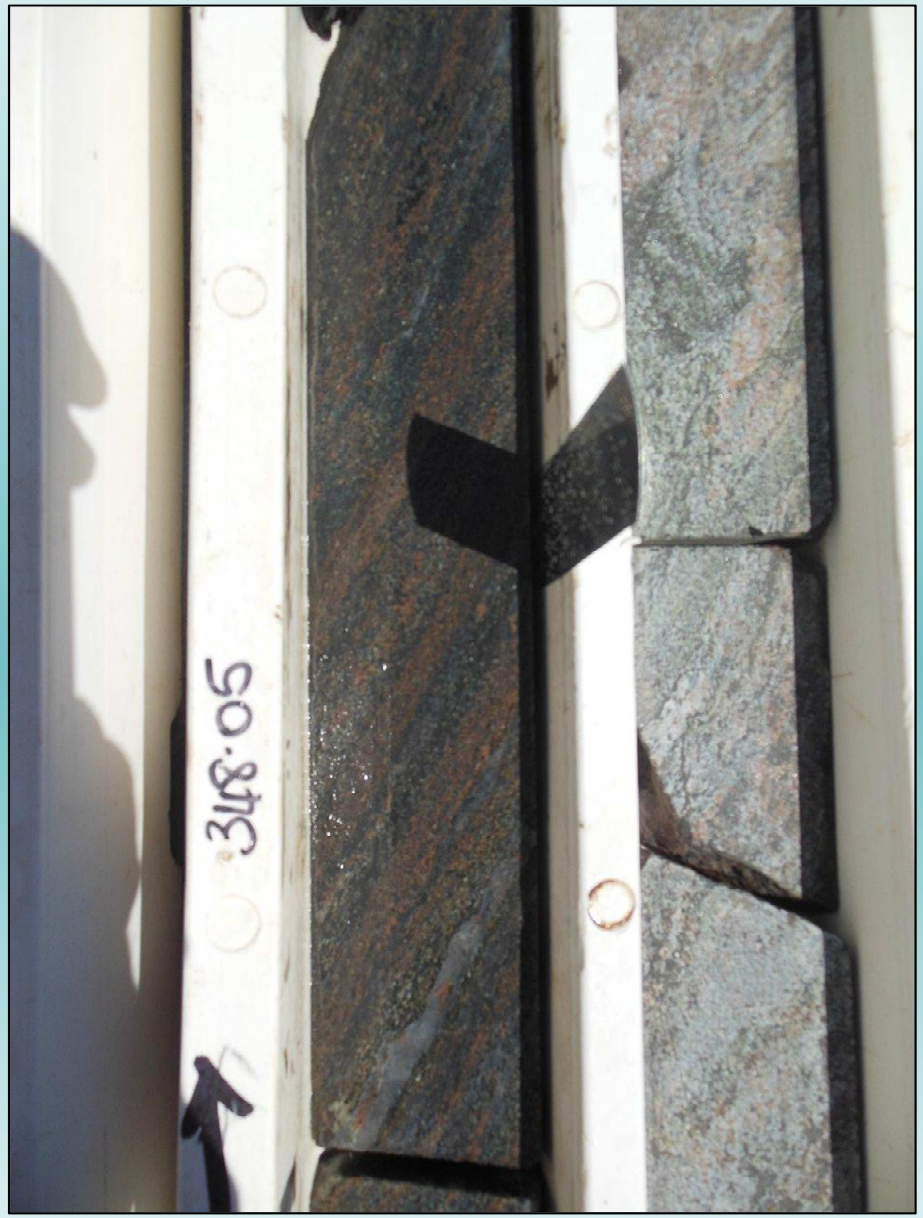
They show a distinct mixing trend between N-MORB and an enriched component.

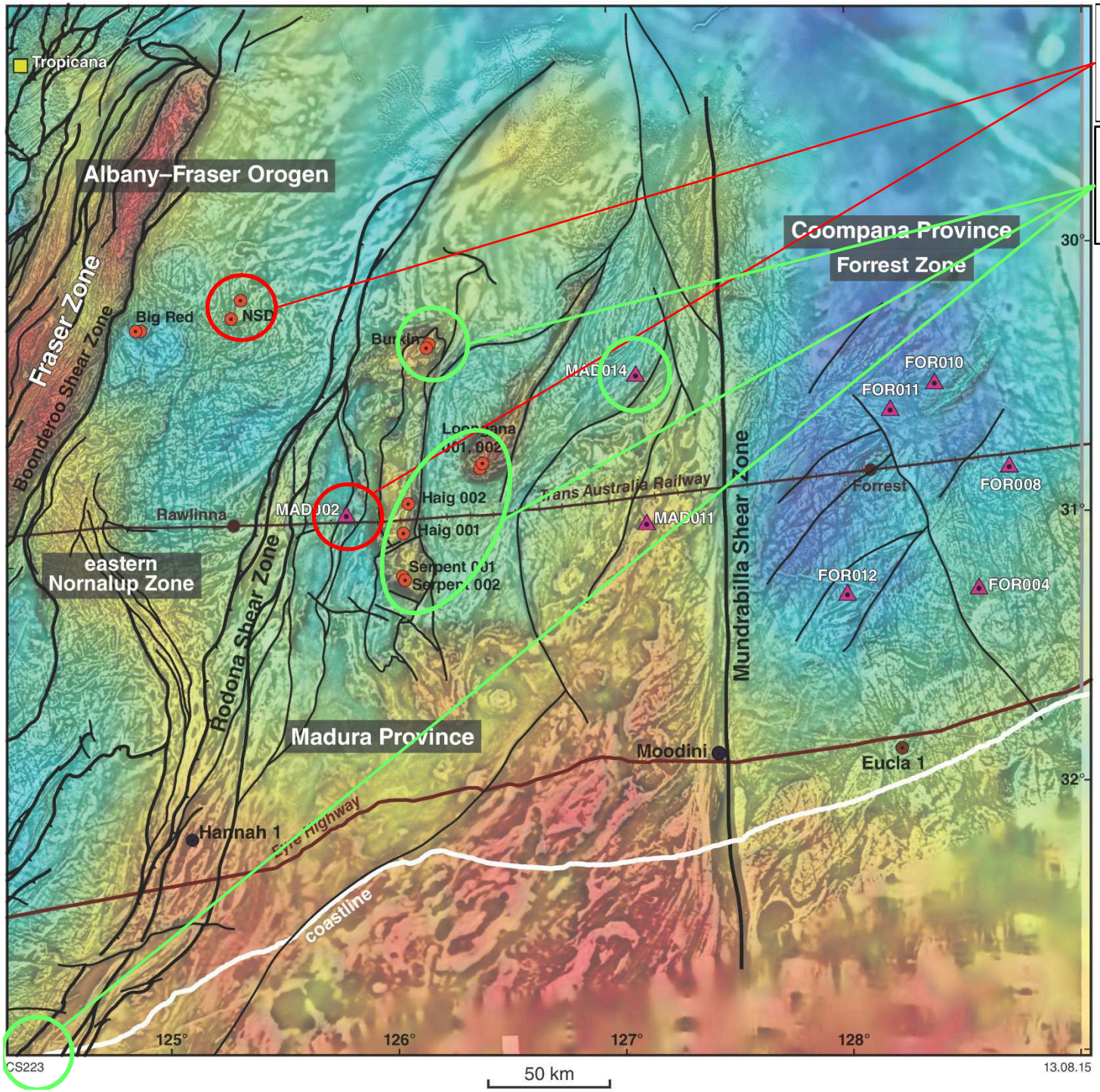
Paradoxically, the high Th/Nb component has the most primitive major element and isotopic composition.

BURKIN

Banded chl, gnt, qtz schist from Burkin BKD1

GSWA	201271	201274
SiO_2	44.74	27.01
TiO_2	0.13	0.15
Al_2O_3	3.48	5.24
$Fe_2O_3^T$	42.83	50.89
MgO	2.00	4.52
MnO	4.80	8.71
CaO	1.45	3.51
K_2O	0.09	0.00
Na_2O	0.02	0.06
P_2O_5	0.52	0.73
Total	99.82	100.68





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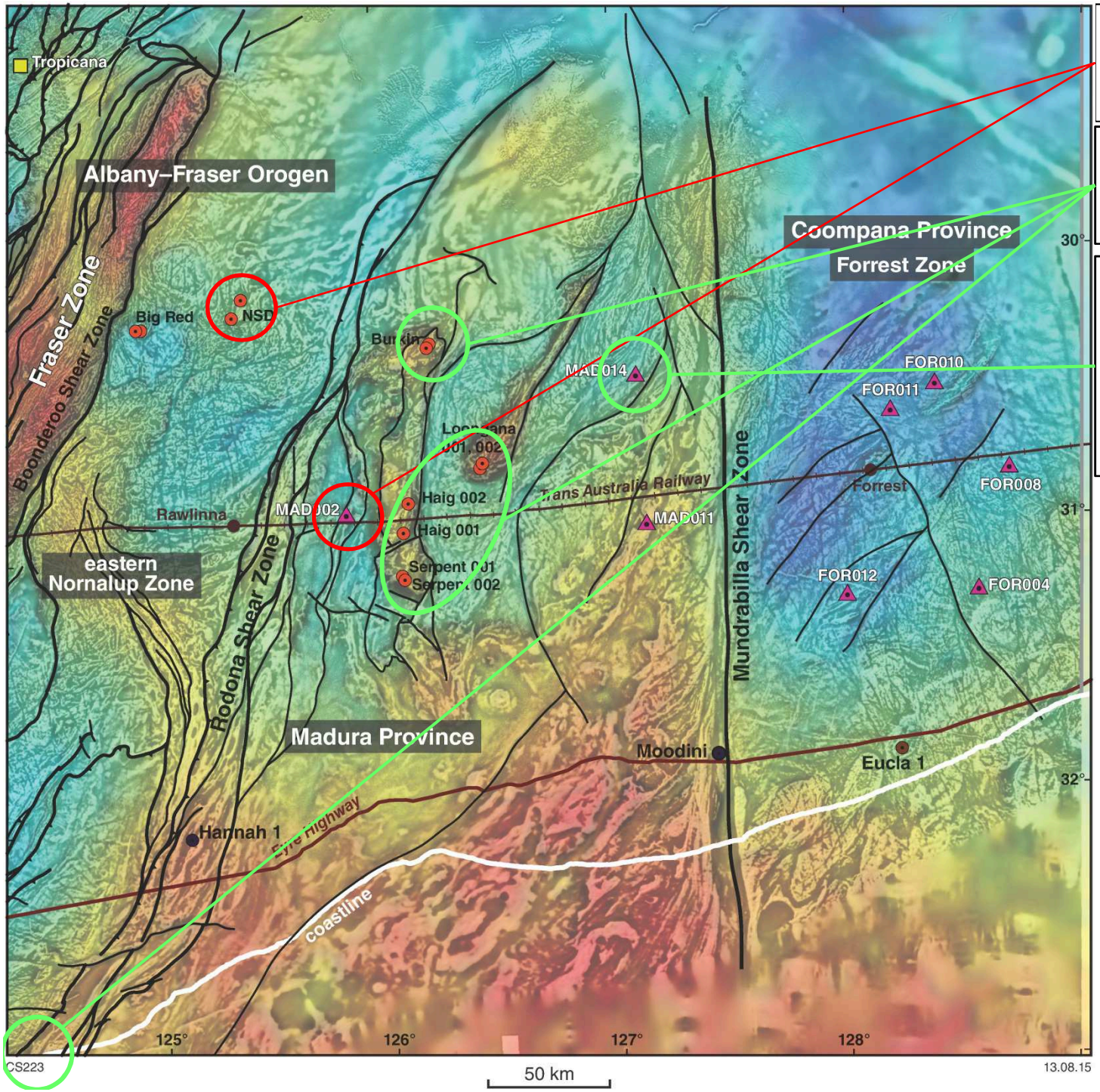
Subduction-modified N-MORB: back- or fore-arc at c. 1400 Ma



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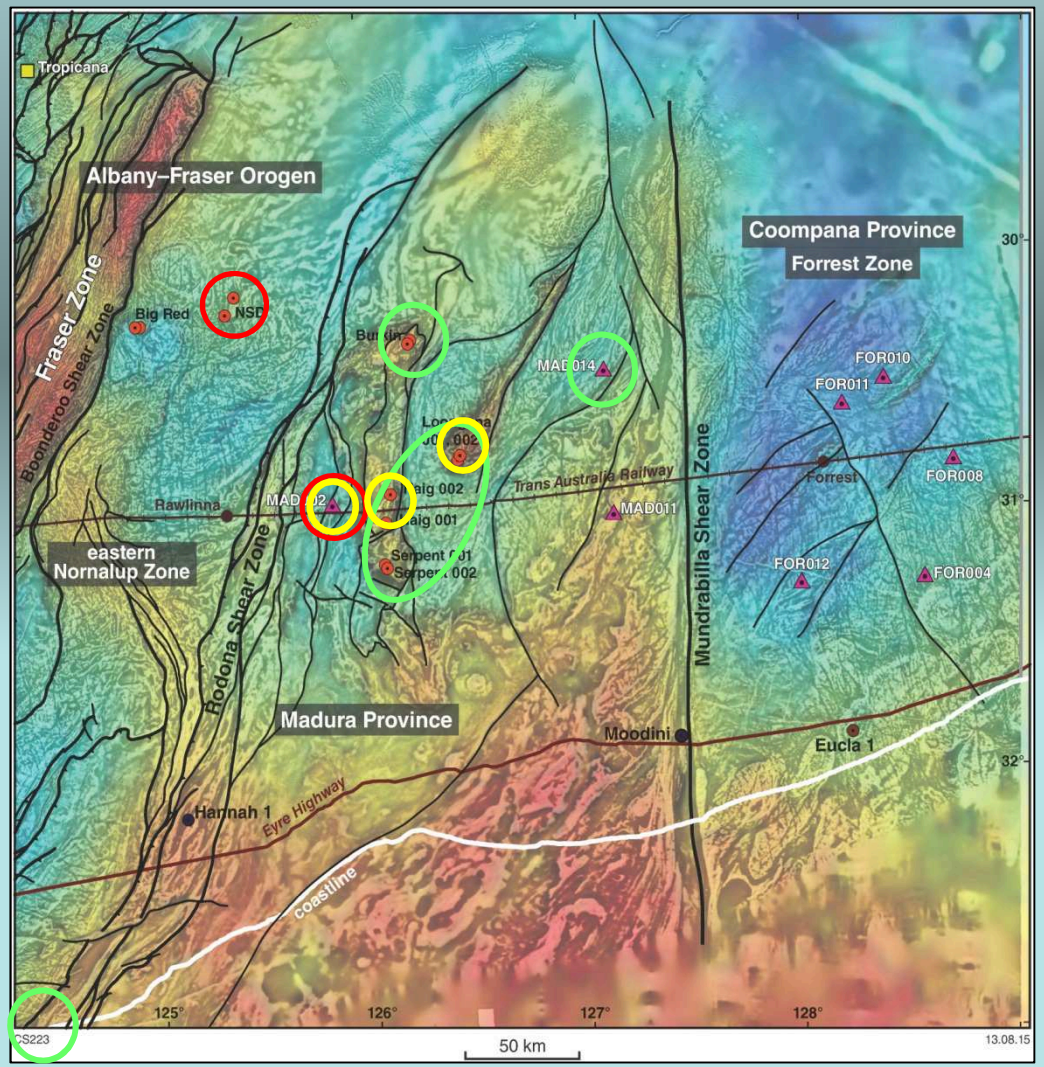
Subduction-modified N-MORB: back- or fore-arc at c. 1400 Ma

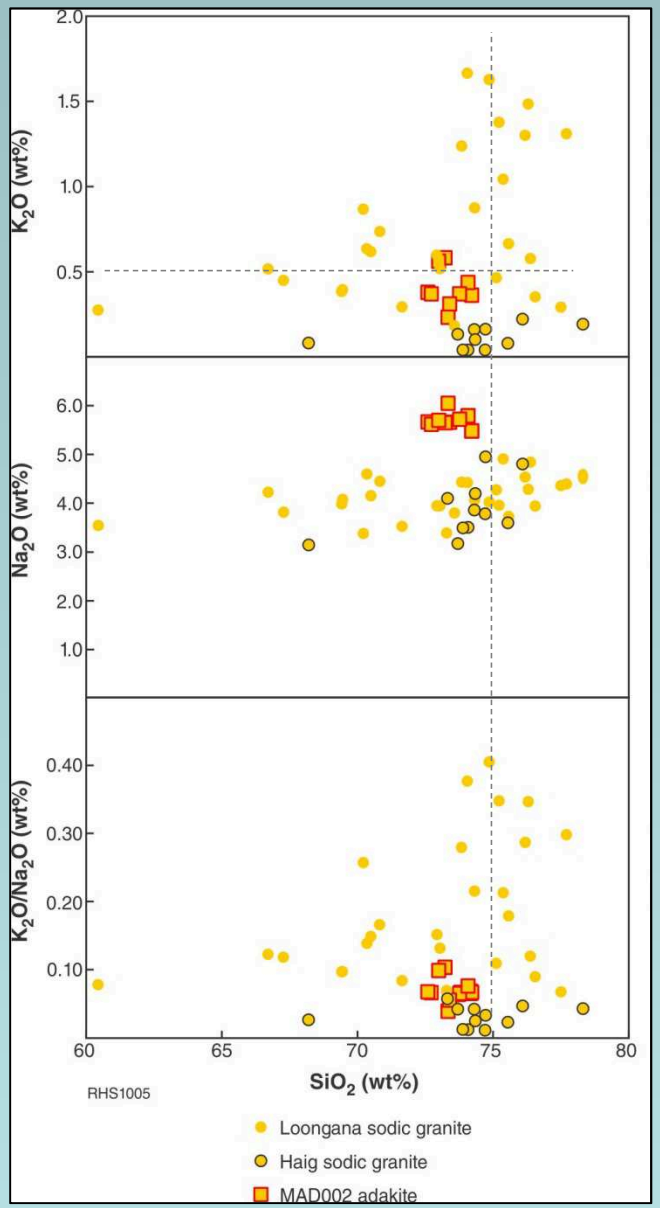
Subduction-modified N-MORB: back- or fore-arc at c. 1400 Ma with contamination by chemically-evolved “cognate” arc-crust

Madura Province c. 1400 Ma

Sodic-plagiogranite: melting primitive arc crust

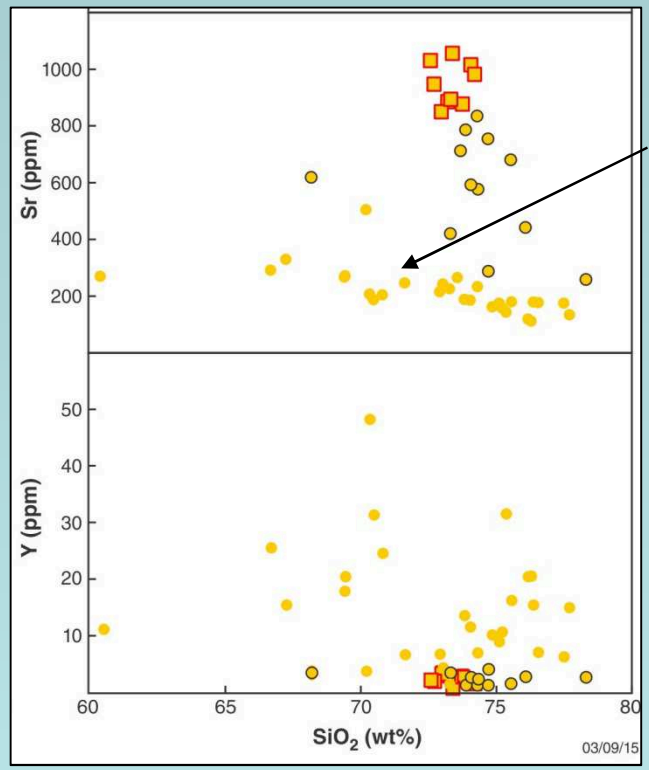


Loongana
Haig
MAD002



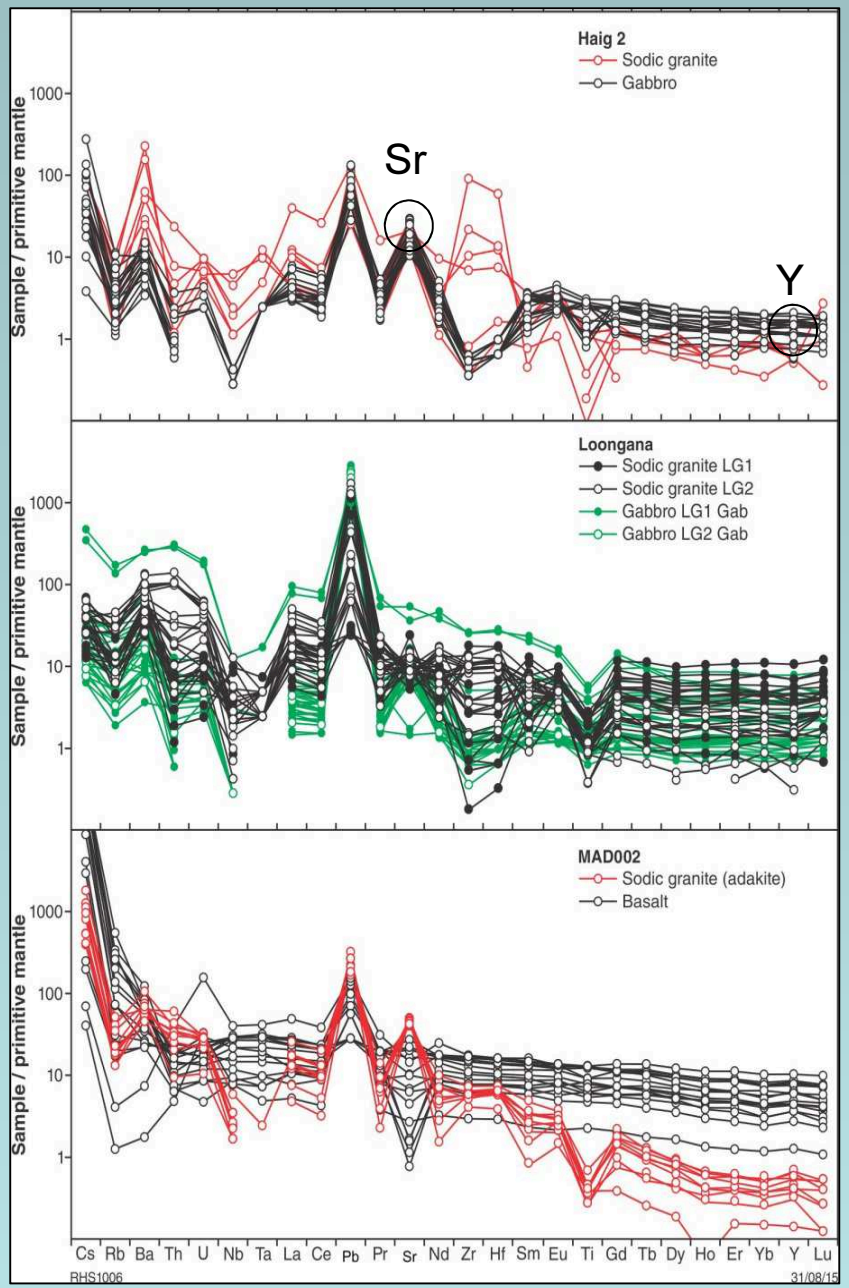
Very low K_2O – whatever the source or process, the source composition itself had extremely low K.

Generally thought to be partial melts of hydrated mafic crust – the bulk source clearly included very little if any 'continental' material.



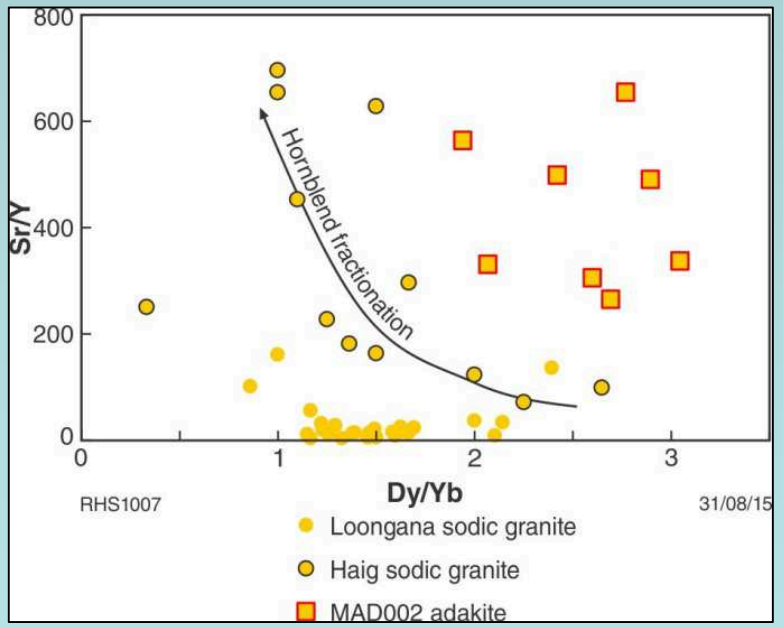
Leucogranites from Loongana, in particular, look very similar to oceanic plagiogranites from ophiolites.

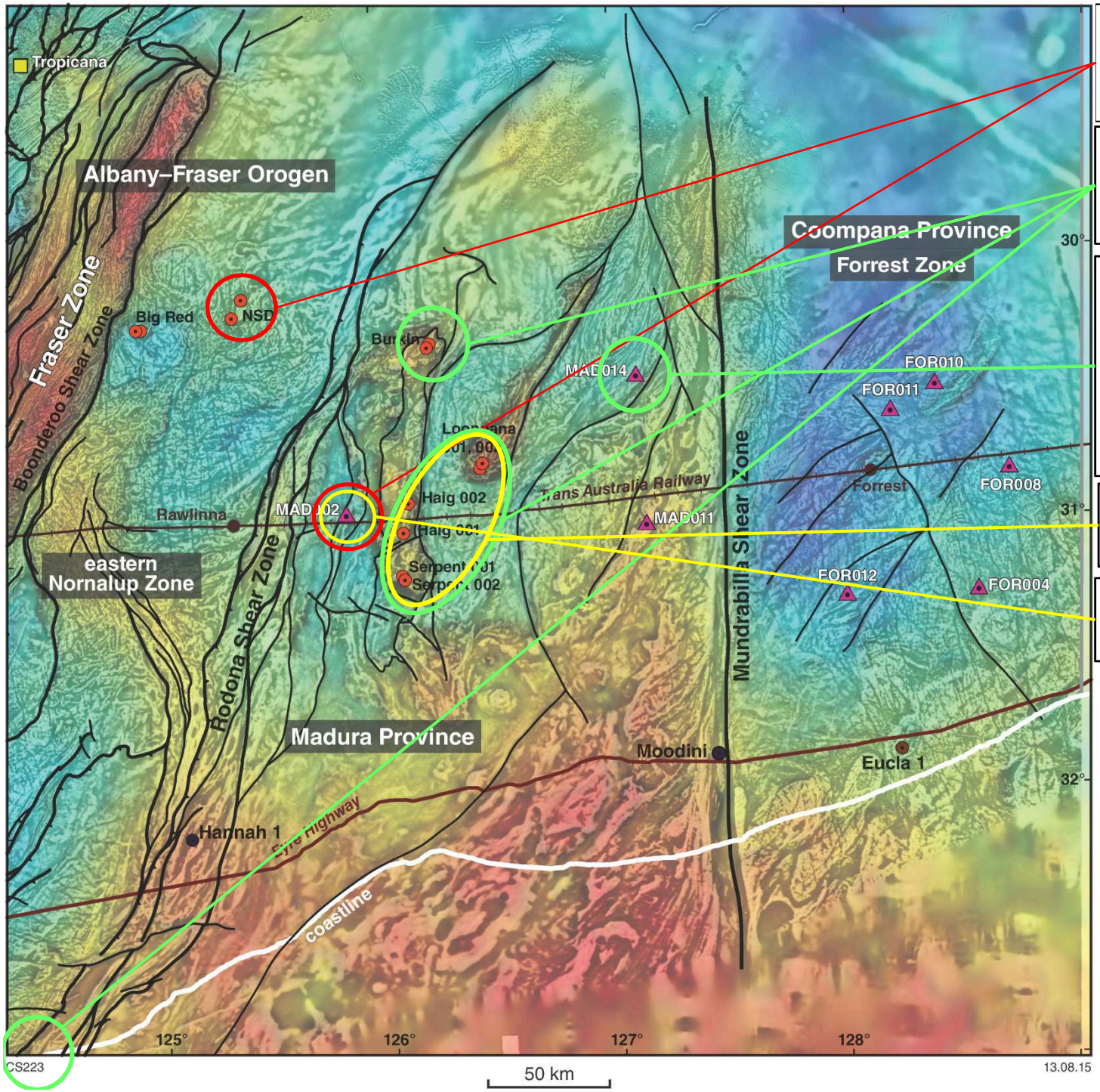
Leucogranites from Haig and MAD002 are Sr-rich and depleted in Y (and HREE)



In the case of Loongana and Haig, the leucogranites share certain compositional characteristics and are mostly isotopically equivalent with the mafic crust that host them. This suggests a strong source-composition control – and may help explain high Sr and low Y in the Haig leucogranites.

MAD002 leucogranites are VERY different to the E-MORB crust they intrude. There are REAL adakites (slab melts/hot-subduction).





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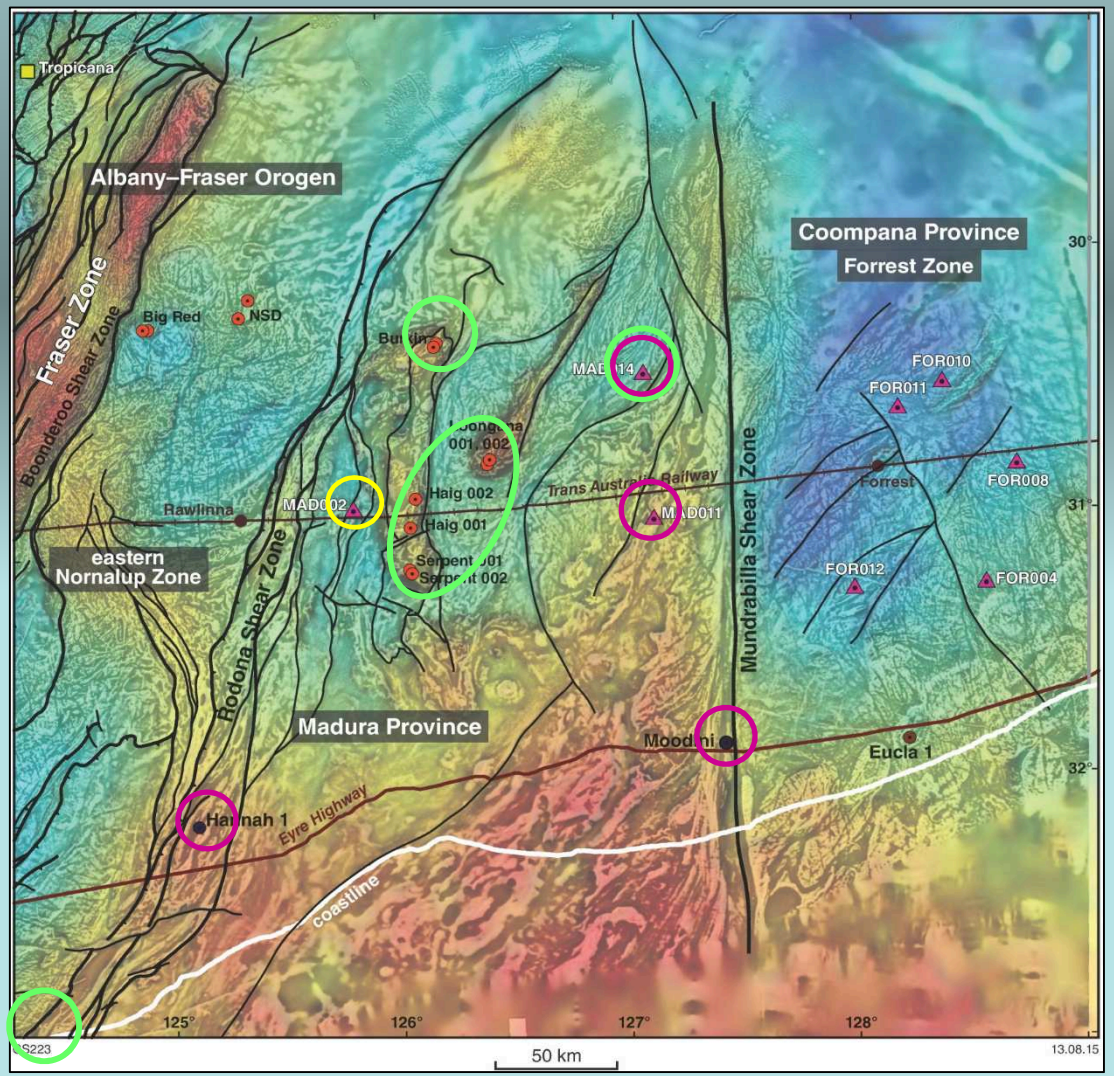
c. 1400 Ma plagiogranite – ‘oceanic’ compositions

Subducted-slab melting at c. 1400 Ma - adakite

Madura Province c. 1180 – 1125 Ma

High-KFe series: high-T melting of extended lower crust

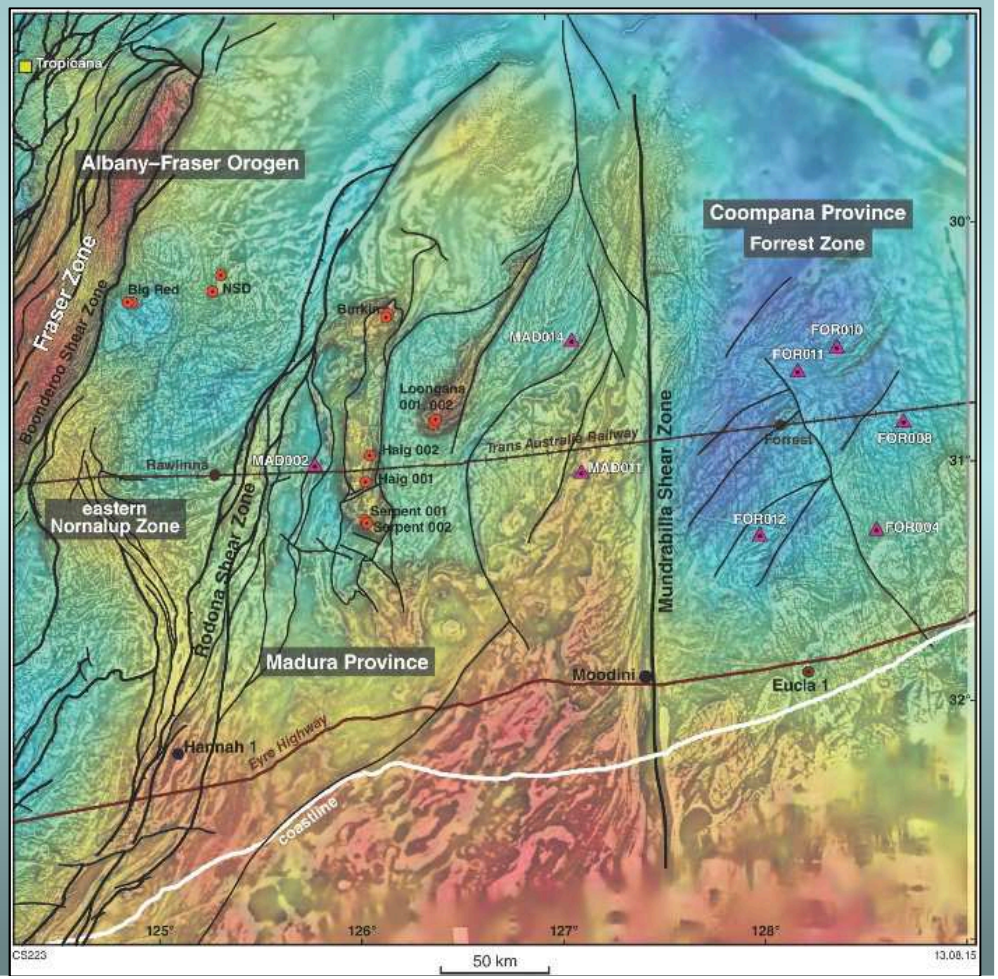


Hannah
MAD011
MAD014
Moodini

Madura Province c. 1180 – 1125 Ma

High-KFe series: high-T melting of extended lower crust

- No record of magmatic activity between c. 1389 Ma and c. 1180 Ma – although we know we have voluminous mafic-felsic magmatism throughout the neighbouring Albany–Fraser Orogen, right up to the current boundary (Rodona Shear Zone) from c. 1320 – 1290 Ma.
- Beginning c. 1180 Ma we have quite geochemically specialized, ferroan magmatism and extrapolating the geophysical footprint of known examples of these rocks, this magmatism was extremely widespread and voluminous.
- Exactly the same style of magmatism also occurred, over the same period, in the neighbouring AFO and Musgrave Province.



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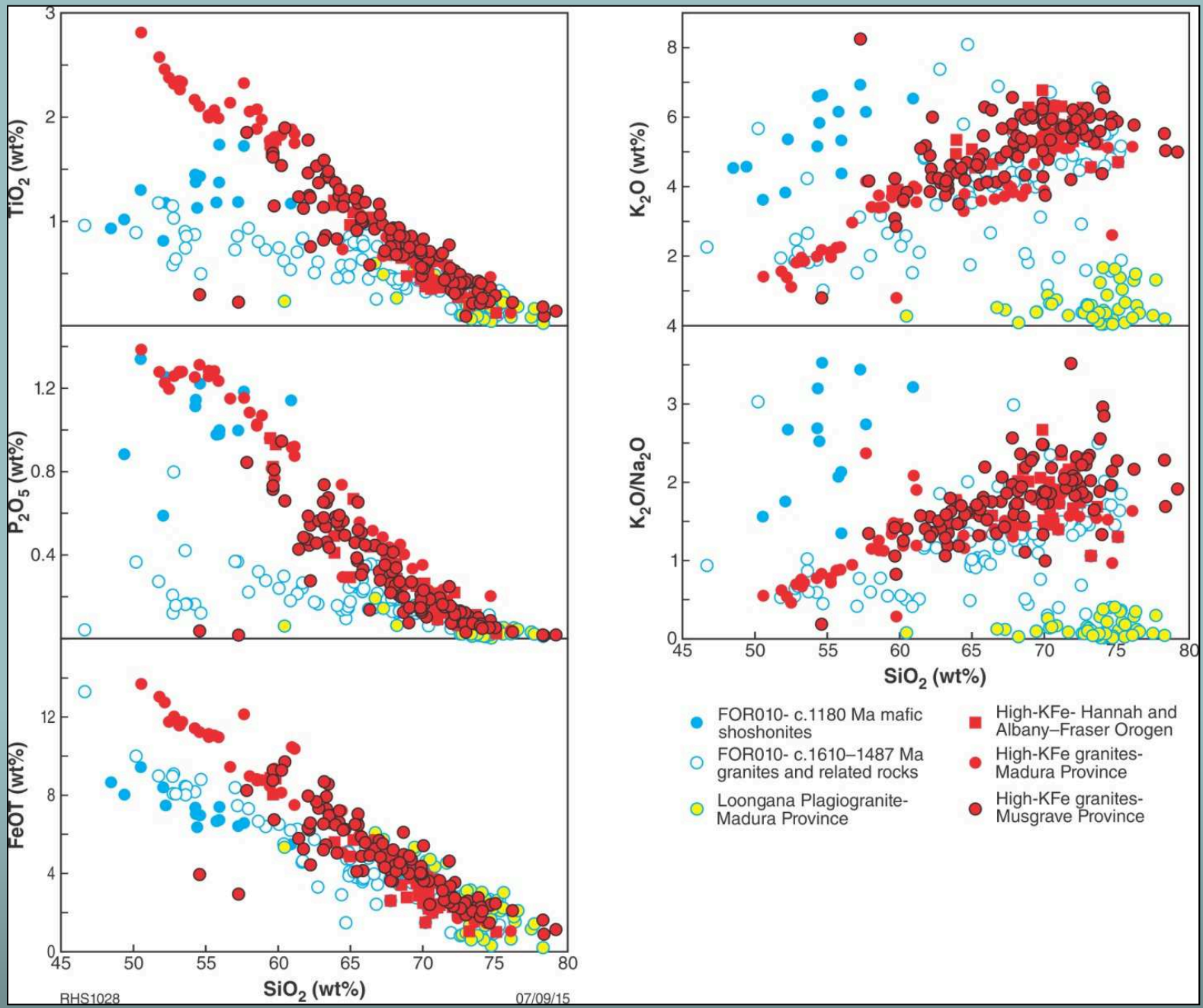
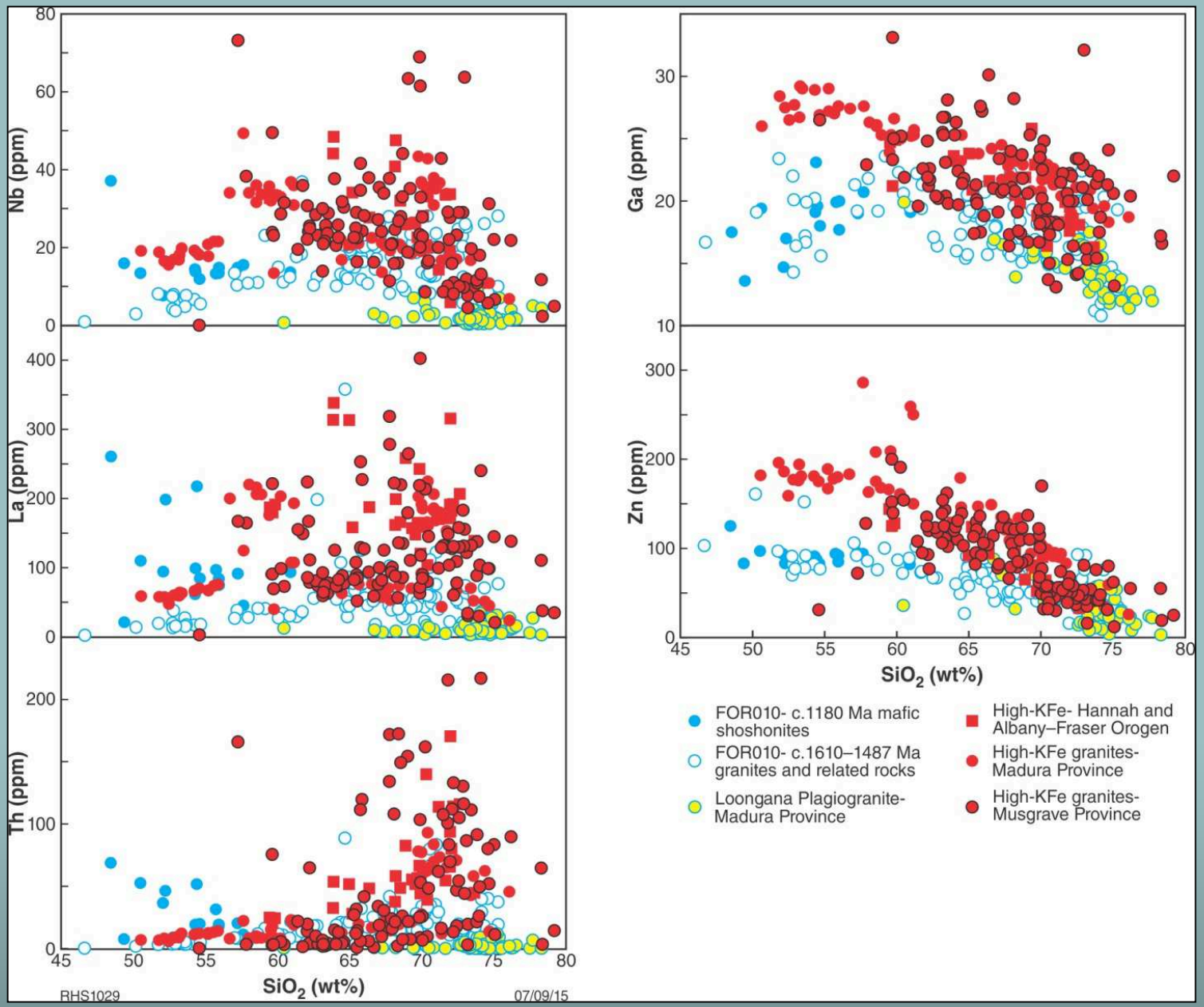
- Include orthopyroxene- and pigeonite-bearing (ferro) monzodiorite and monzonite (jontunites) to biotite-monzogranite.
- Geochemically specialised – high K, Fe, Ti, P, HFSE, REE, Th, U – A-type


TiO2 (wt%)
P2O5 (wt%)
FeOT (wt%)
SiO2 (wt%)
K2O (wt%)
K2O/Na2O
SiO2 (wt%)
RHS1028
07/09/15
FOR010- c.1180 Ma mafic shoshonites
FOR010- c.1610–1487 Ma granites and related rocks
Loongana Plagiogranite-Madura Province
High-KFe- Hannah and Albany–Fraser Orogen
High-KFe granites-Madura Province
High-KFe granites-Musgrave Province

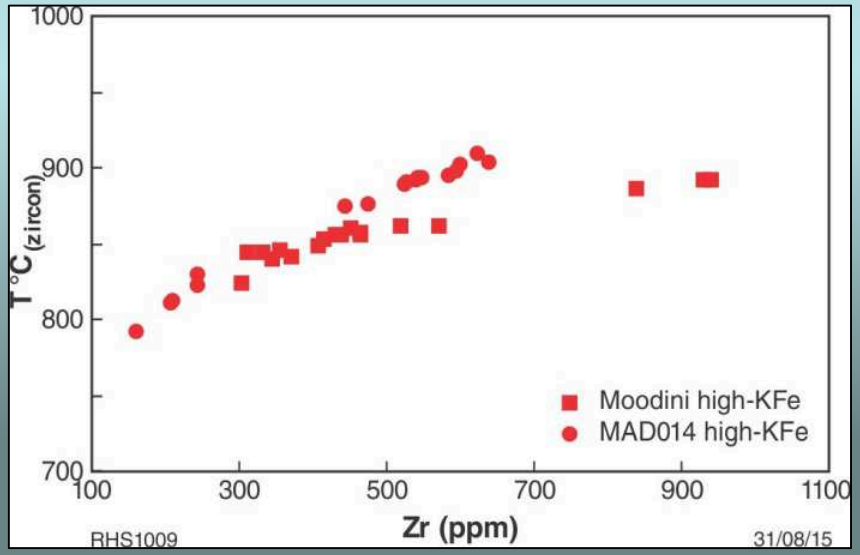

Nb (ppm)
La (ppm)
Th (ppm)
Ga (ppm)
Zn (ppm)
SiO2 (wt%)
SiO2 (wt%)
RHS1029
07/09/15
FOR010- c.1180 Ma mafic shoshonites
FOR010- c.1610–1487 Ma granites and related rocks
Loongana Plagiogranite-Madura Province
High-KFe- Hannah and Albany–Fraser Orogen
High-KFe granites-Madura Province
High-KFe granites-Musgrave Province

Madura Province c. 1180 – 1125 Ma

High-KFe series: high-T melting of extended lower crust

- No record of magmatic activity between c. 1389 Ma and c. 1180 Ma – although we know we have voluminous mafic-felsic magmatism throughout the neighbouring Albany–Fraser Orogen, right up to the current boundary (Rodona Shear Zone) from c. 1320 – 1290 Ma.
- Beginning c. 1180 Ma we have quite geochemically specialised, ferroan magmatism and extrapolating the geophysical footprint of known examples of these rocks, this magmatism was extremely widespread and voluminous.
- Include orthopyroxene- and pigeonite-bearing monzodiorite and monzonite (jontunites) to biotite-monzogranite.
- Geochemically specialised – high K, Fe, Ti, P, HFSE, REE, Th, U – A-type.

- Intrusive temperatures often > 900°C (mafic member >1000°C)



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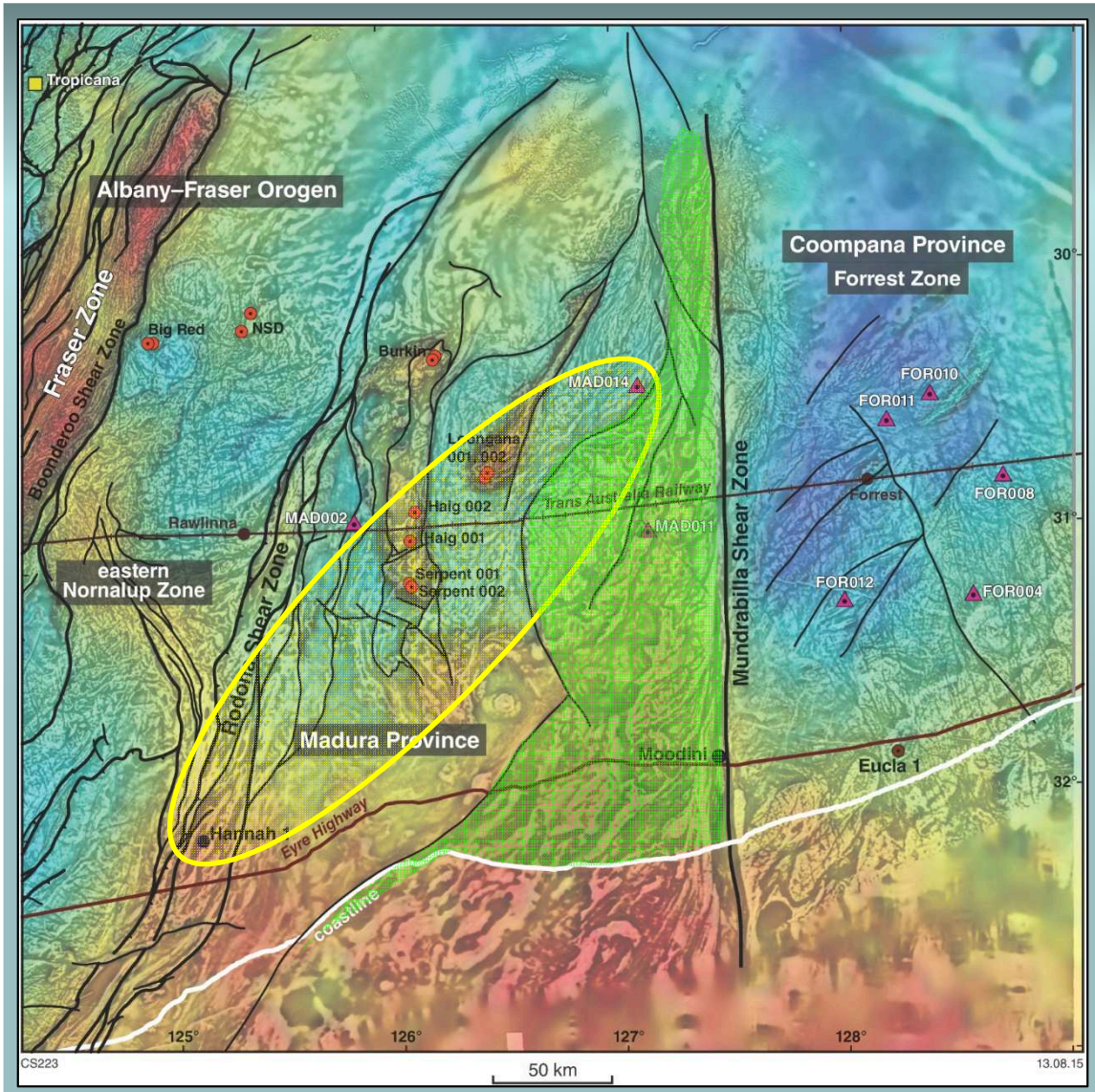
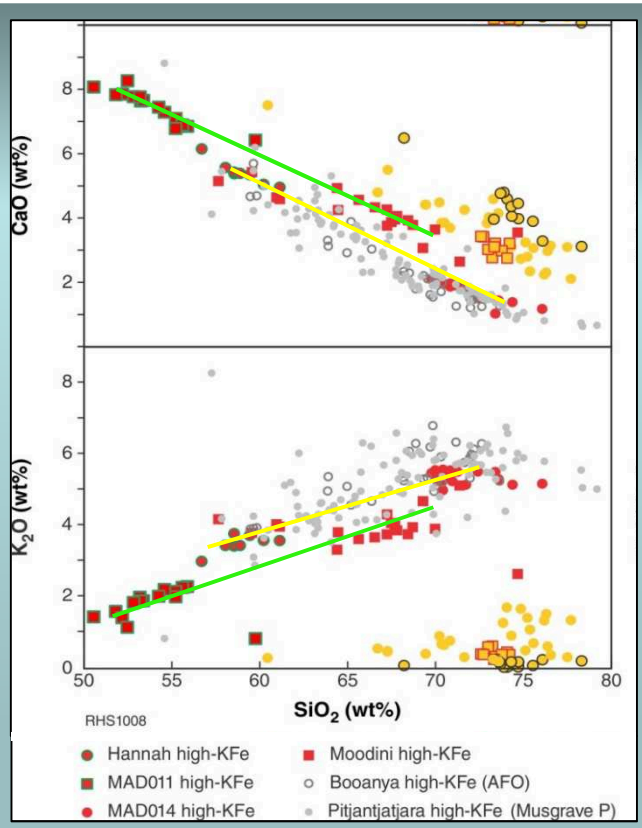
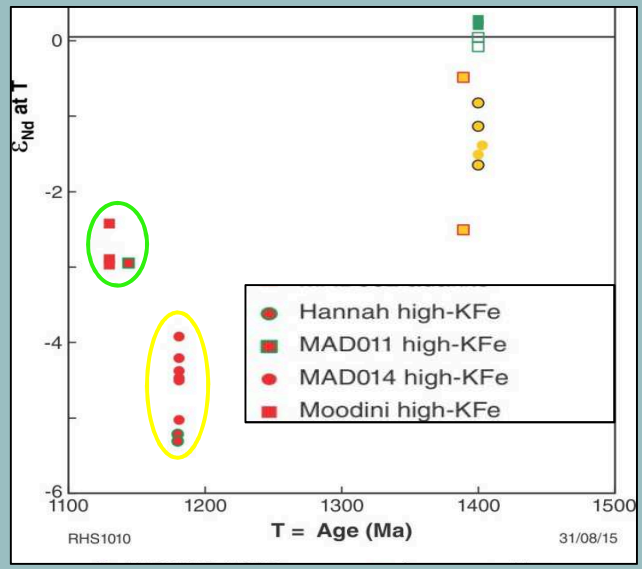
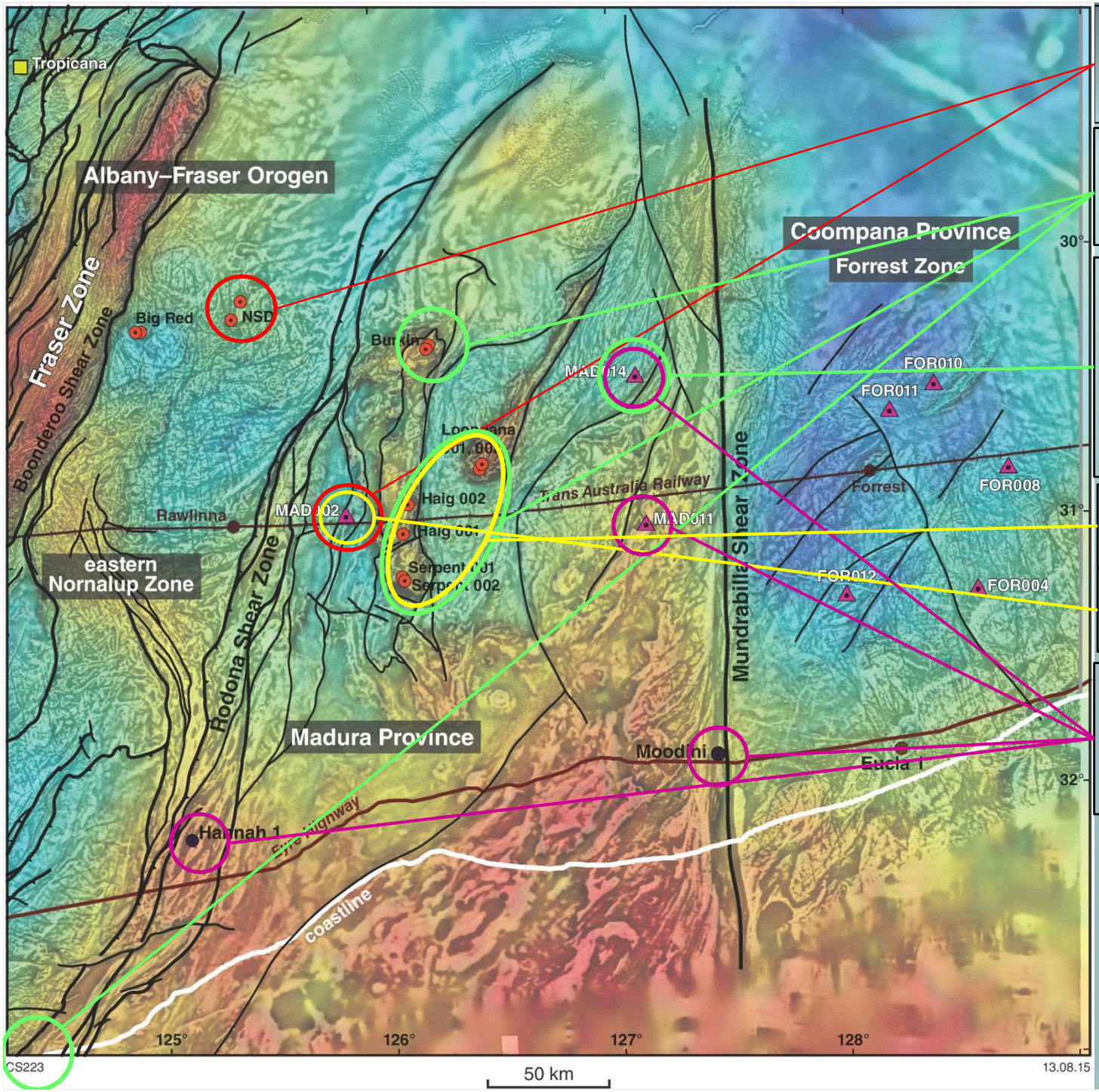
- We can still identify basement domains







High-KFe magmatism in the MAD011 – Moodini region is younger and geochemically and isotopically more primitive than in the Hannah – MAD014 region



E-MORB/OIB
>> c. 1400 < 1950 Ma
Continental rifting?

Subduction-modified N-MORB: back- or fore-arc at c. 1400 Ma

Subduction-modified N-MORB: back- or fore-arc at c. 1400 Ma with contamination by chemically-evolved “cognate” arc-crust

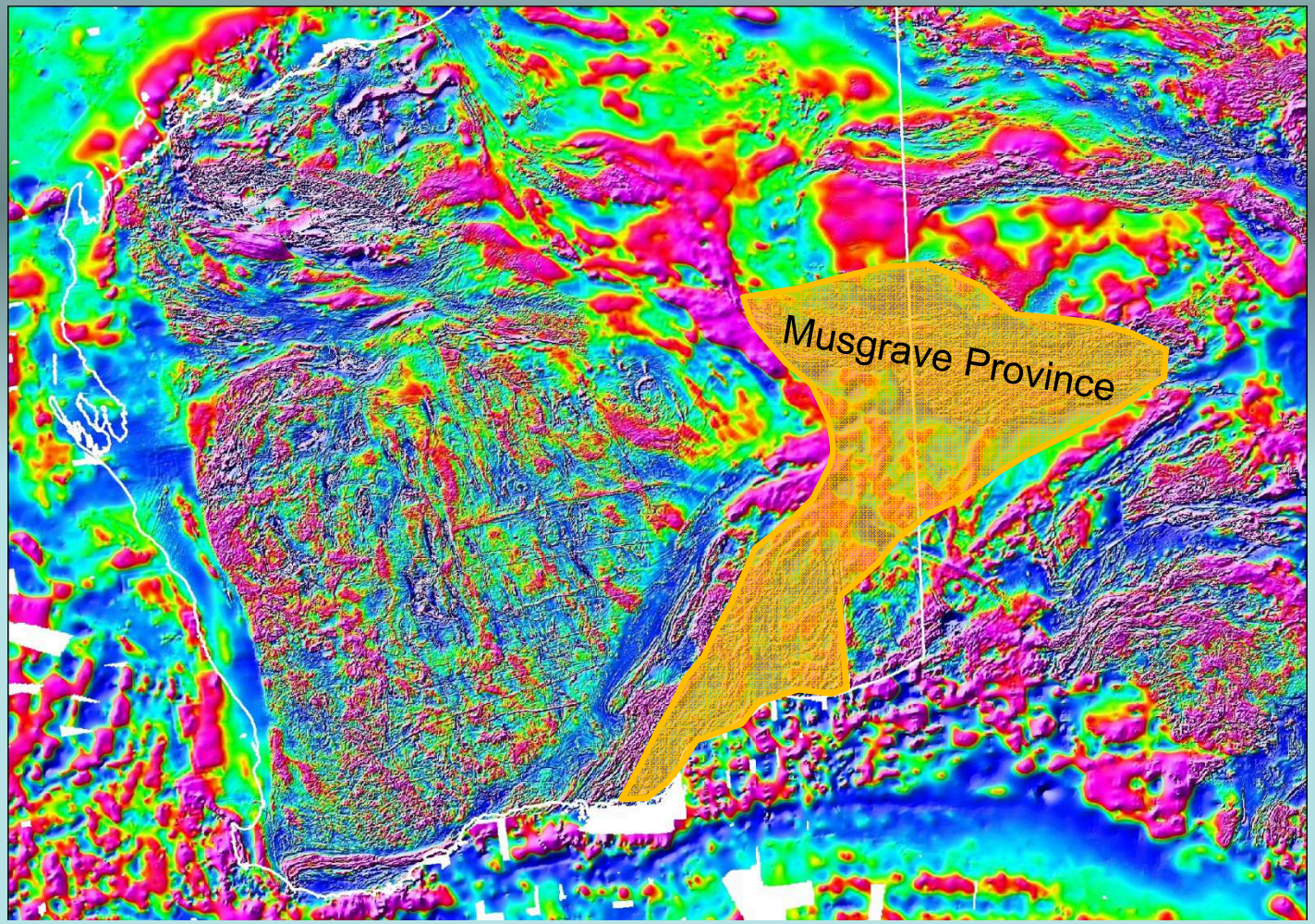
c. 1400 Ma plagiogranite – ‘oceanic’ compositions

Subducted-slab melting at c. 1400 Ma - adakite

Lithospheric extension and removal; mantle upwelling; high-temperature melting

High-KFe series: a more regional view

High-KFe magmas swamped the Madura Province, Albany–Fraser Orogeny and the Musgrave Province over the same period forming an extraordinarily large tract of contiguous, highly specialise, very high-temperature magmatism almost certainly reflecting a very specific and unusual regional tectonic setting.



High-KFe series: a more regional view

This event had an even wider magmatic and metamorphic footprint – seen widely throughout the Arunta and (as we will see) throughout the Forrest Zone. Equally importantly, throughout an even greater region than that of the exposed high-KFe magmas, 1220 – 1120 Ma magmatism recycles what is geochronologically and isotopically exactly the same piece of juvenile crust