Stratigraphy, Age and Provenance of Madura Shelf Sediments, WA: Implications for the Evolution of the Bight Basin and Australia's Southern Margin*

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Search and Discovery Article #10819 (2015)**
Posted December 28, 2015

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

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Abstract

The expansive Cenozoic carbonates of the Nullarbor Plain veneer older sediments that preserve an important record of Australia's rifting from Antarctica, and development of the present-day southern passive margin. Importantly, the sediments of the onshore extension of the Bight Basin (Madura Shelf) are far more accessible than those of contemporaneous offshore sub-basins within the Bight, but remain poorly studied despite their relevance to understanding this frontier petroleum province. Stratigraphic logging of newly available boreholes drilled within the WA portion of the Madura Shelf has been combined with pre-existing well-data to enhance 3D stratigraphic modelling within a GIS database. New stratigraphic units have been identified underlying the Mesozoic sequence of the Madura Shelf, which testify to pre-existing depocentres along the southern margin of Australia that may have influenced its later development. Through palynology, it has been possible to resolve the relative timing and environment of deposition of lithostratigraphical units across the Madura Shelf. Localised anomalies in the development of the Madura Shale suggest movement occurred during the Cretaceous along faults that may be correlated into 2D seismic lines offshore. However, by the end of the Cretaceous, the Madura Shale had blanketed all significant pre-existing topography, with the preserved surface showing little evidence for any later disturbance. In-fact, enigmatically, neither the Madura Shale itself, nor its upper surface, evidence the extended periods of time they represent, with little variability/cyclicity or indicators of erosion preserved. Analysis of detrital zircon age-populations recovered from the major stratigraphic units encountered beneath the Eucla Basin, and comparison with sediments from Cenozoic shorelines and the Cretaceous Ceduna Delta indicate:

(i) Dominance of Musgrave Province- or Albany-Fraser-sourced sediment.
(ii) That these sediment pathways were long-lived.
(iii) That a partitioning/disconnection existed between the sediment systems operating in the eastern and western Bight Basin, with little to no sediment from the east being supplied to the west.

(iv) That essentially syn-depositional mid-Cretaceous volcanism occurred in the western Bight Basin. This previously unrecognized Cretaceous western volcanic activity may provide important age constraints and correlation opportunities, as well as having implications for the thermal history of the margin.

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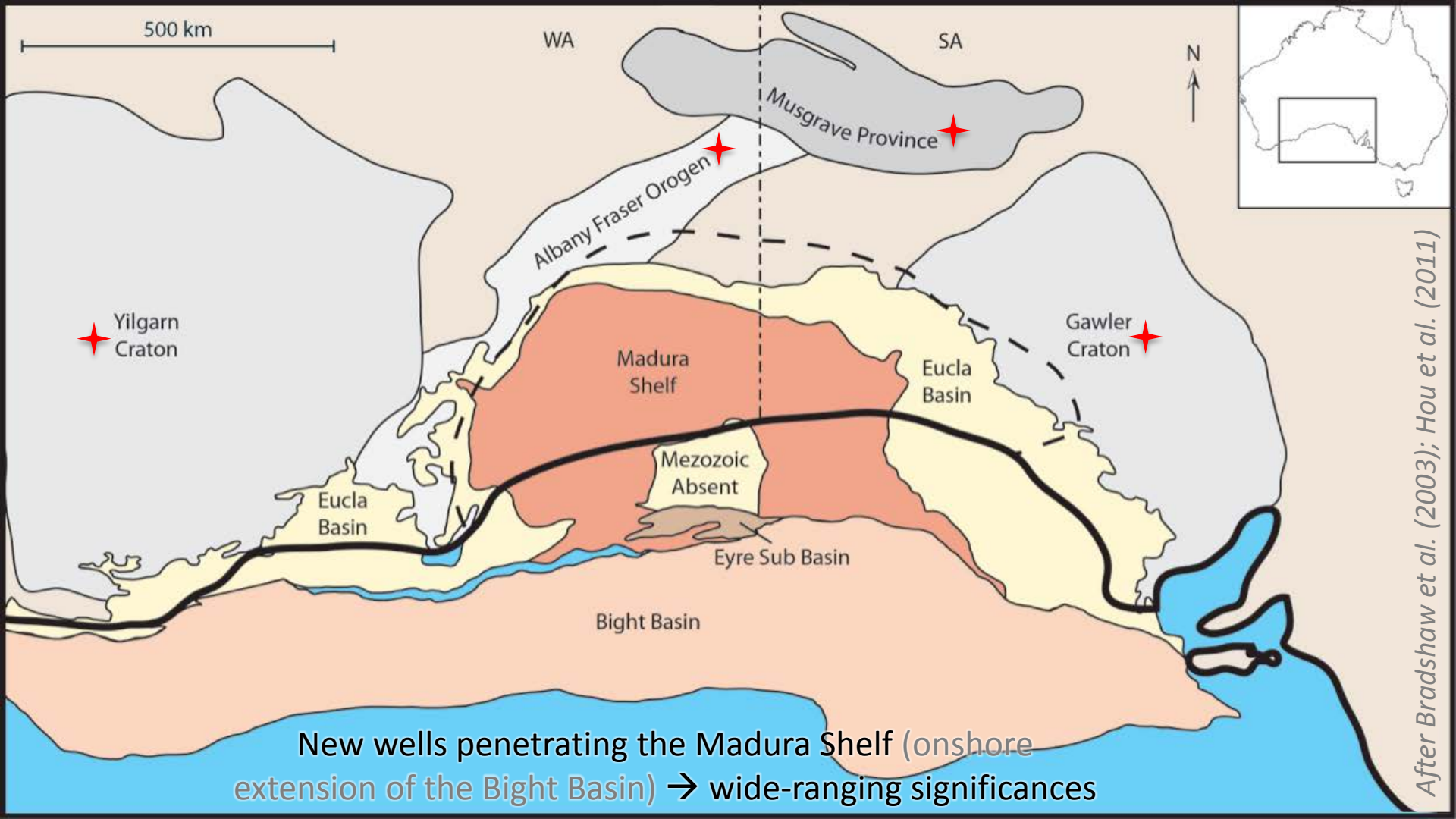
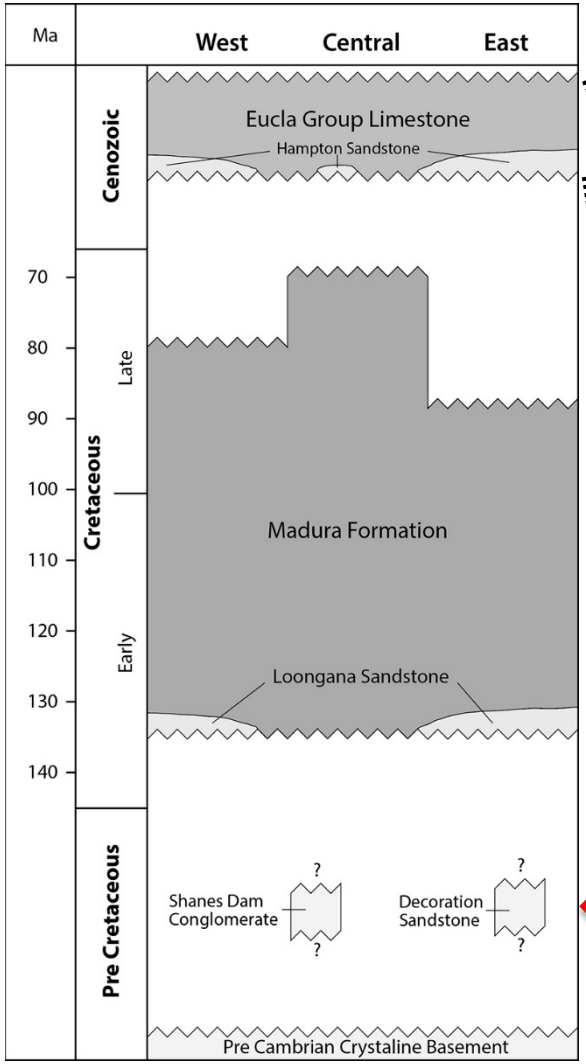
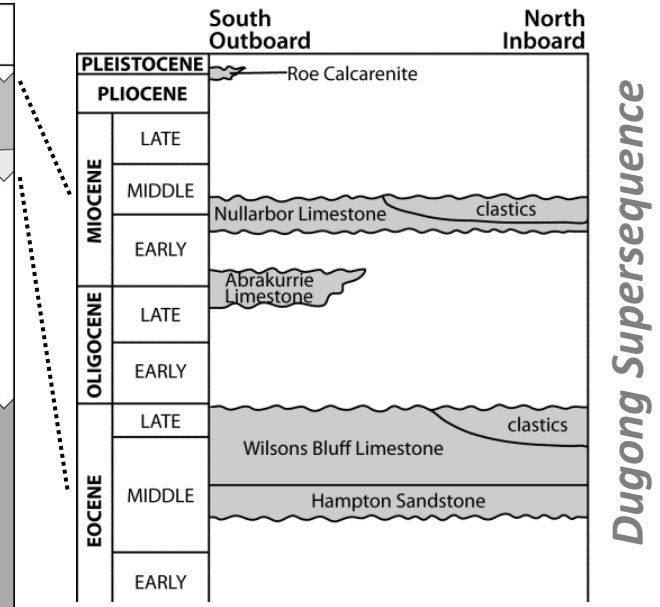


New wells penetrating the Madura Shelf (onshore extension of the Bight Basin) → wide-ranging significances

Generalised stratigraphy of region for WA

Adapted from Lowry (1970); Totterdell and Krassay (2003)



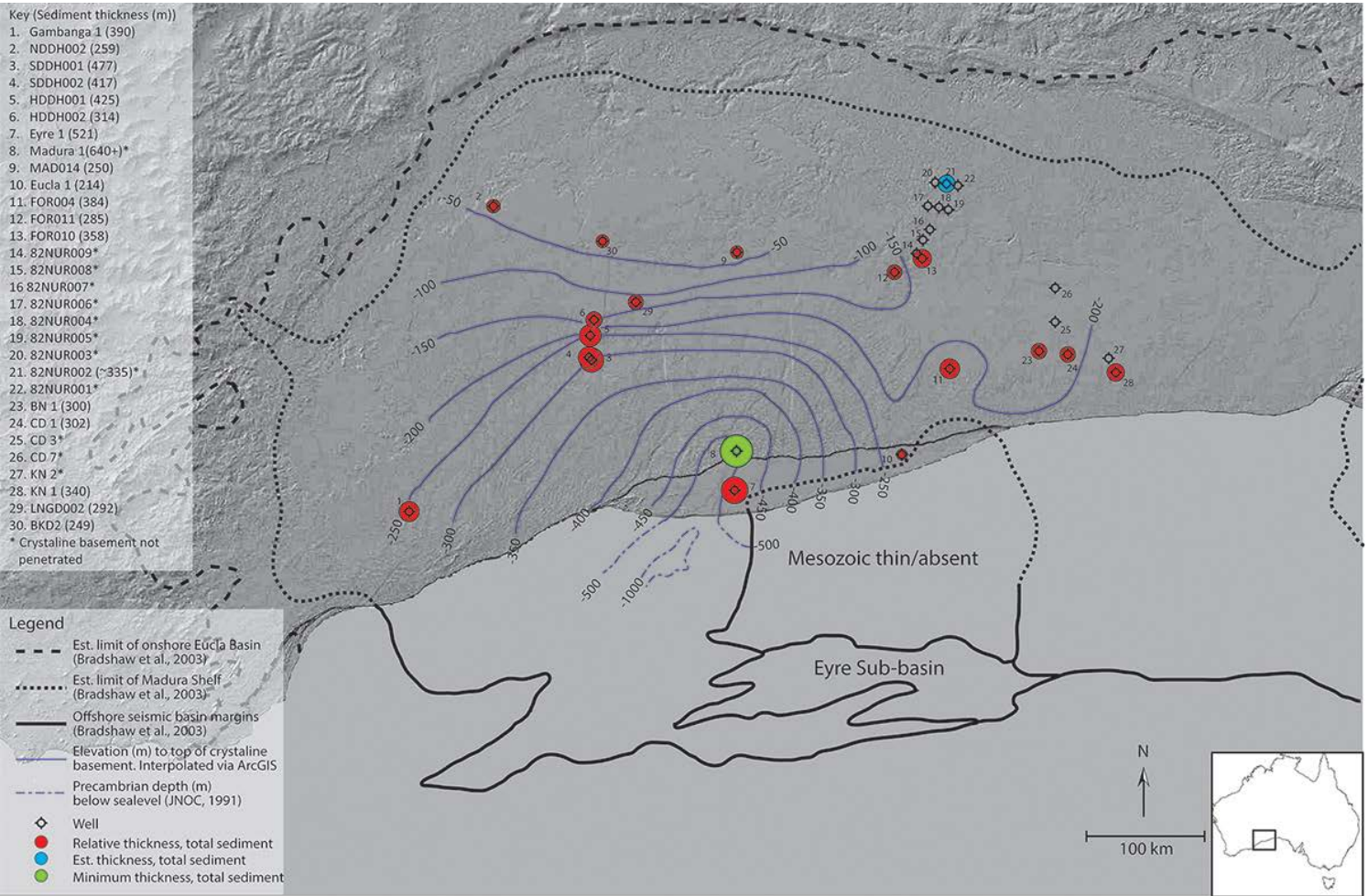


New, previously unknown sedimentary sequences.

Madura Shelf sequence comprises basal clastics overlain by siltstones and shales, becoming more obviously marine upwards. Approximately equivalent to Bronze Whaler to Hammerhead Supersequences.

Disconformably overlain by Eucla Gp. (DT playground)

Basement elevation and sediment thickness



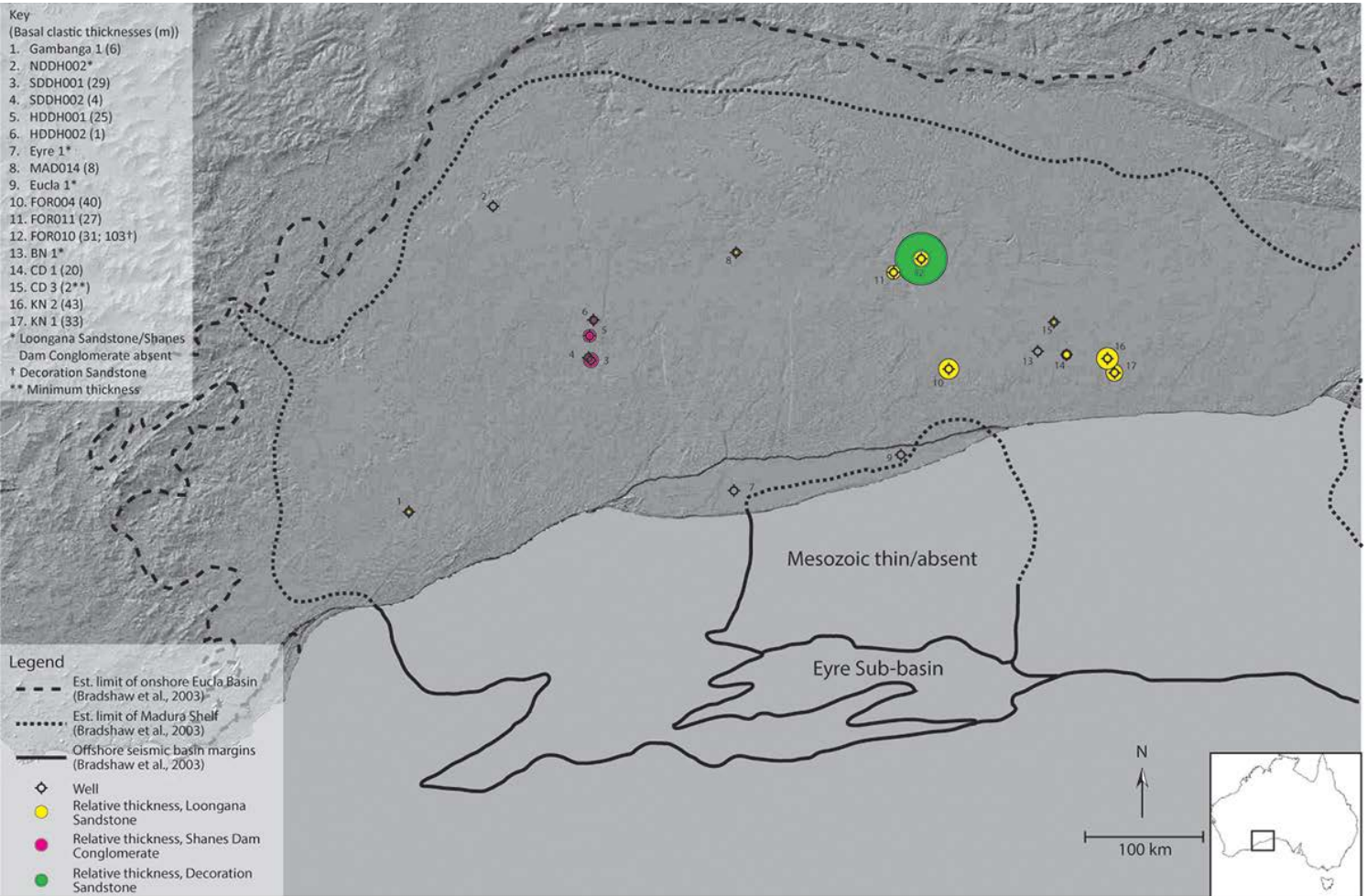
New borehole data (GSWA stratigraphic program and EIS) → GIS database of stratigraphy

Regional gentle S-dipping basement (~0.2˚)

Local irregularities (~60m over 1.8km)

Offshore graben structures trend towards deepest part of Madura Shelf at Eyre 1

Basal clastics distribution

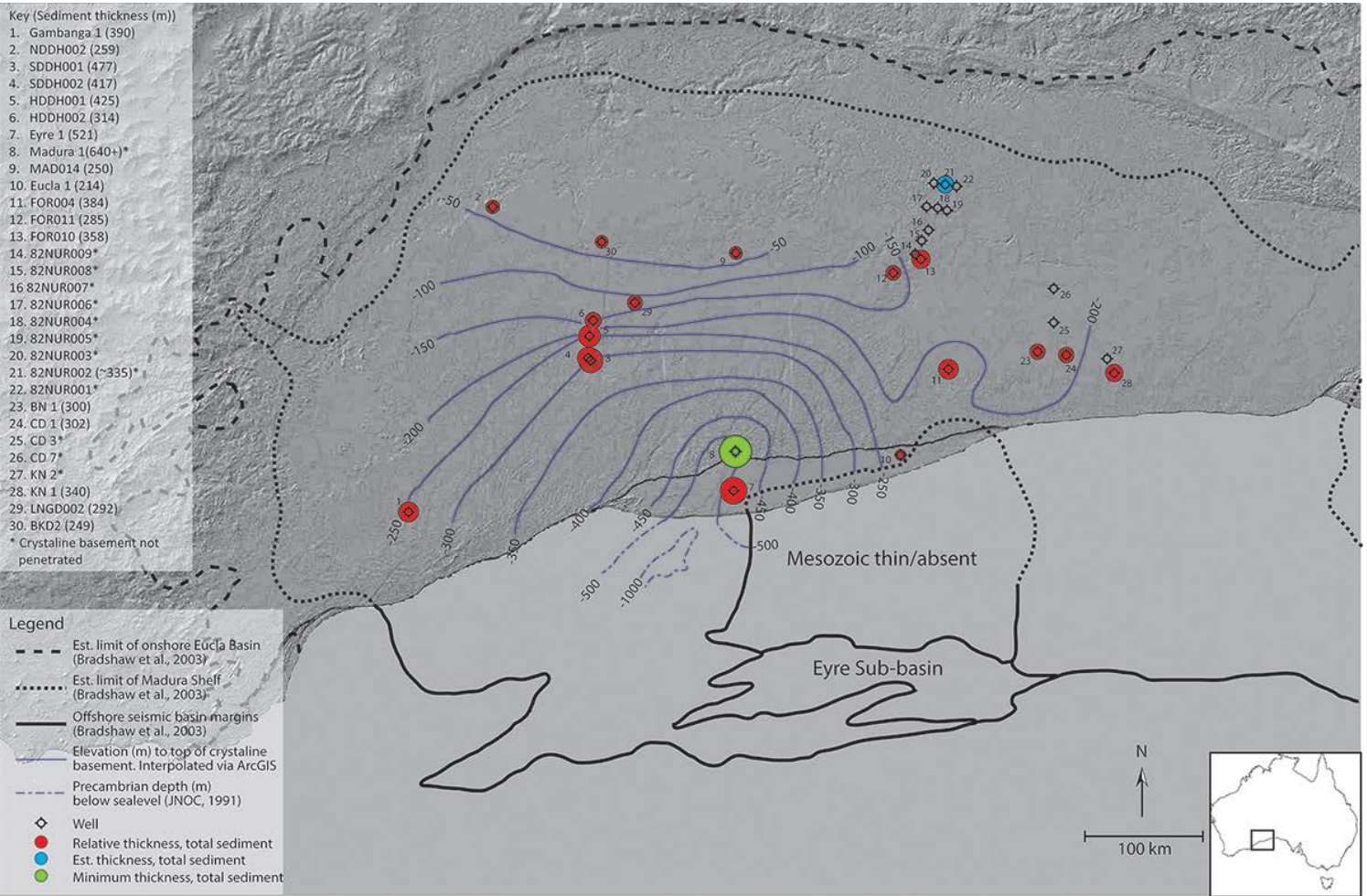


Apparent isolation of sedimentation on irregular surface at different times

Ages not well-constrained for Shanes Dam Conglomerate and Decoration Sandstone

However, paucity of deeper penetrating boreholes prevents fine resolution of seds or basement

Madura Formation development

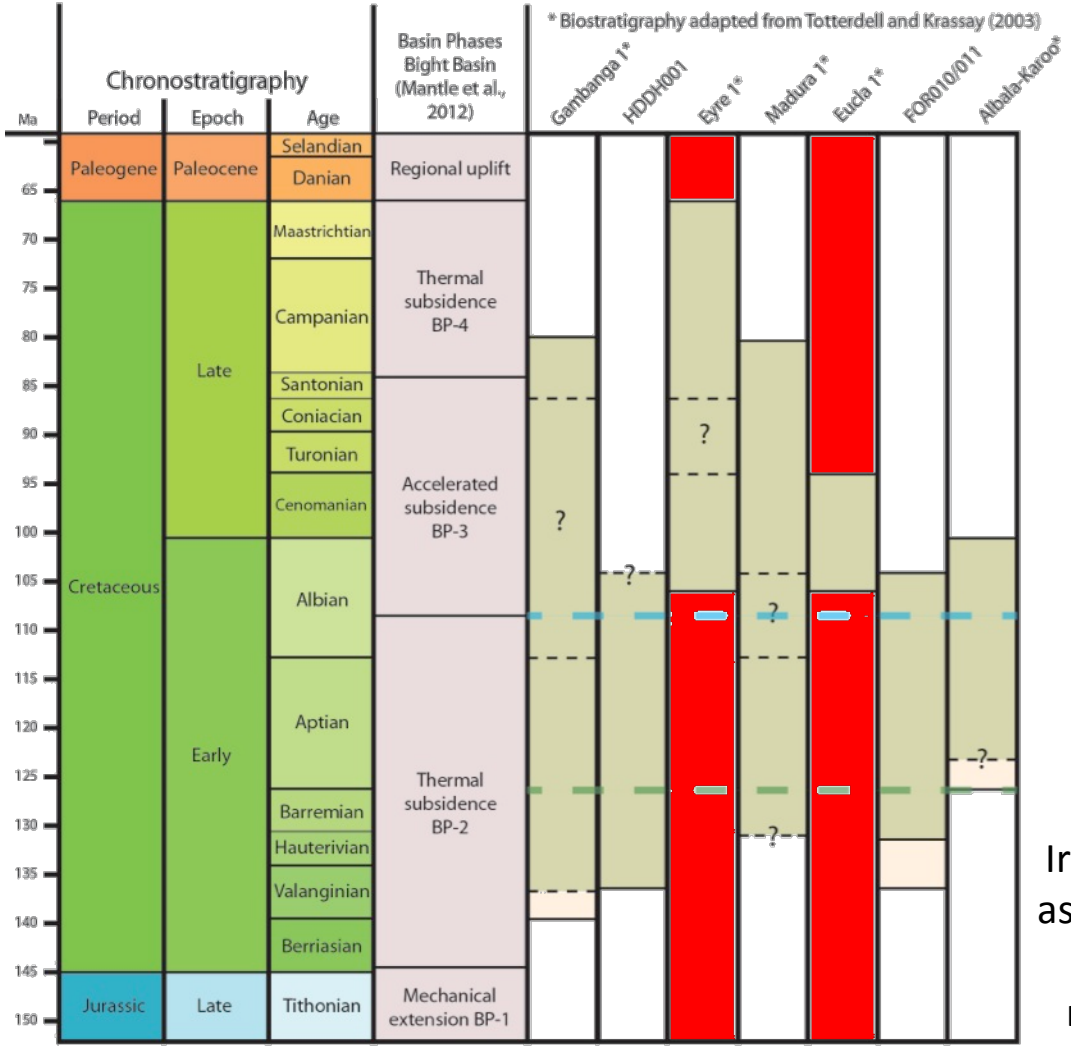


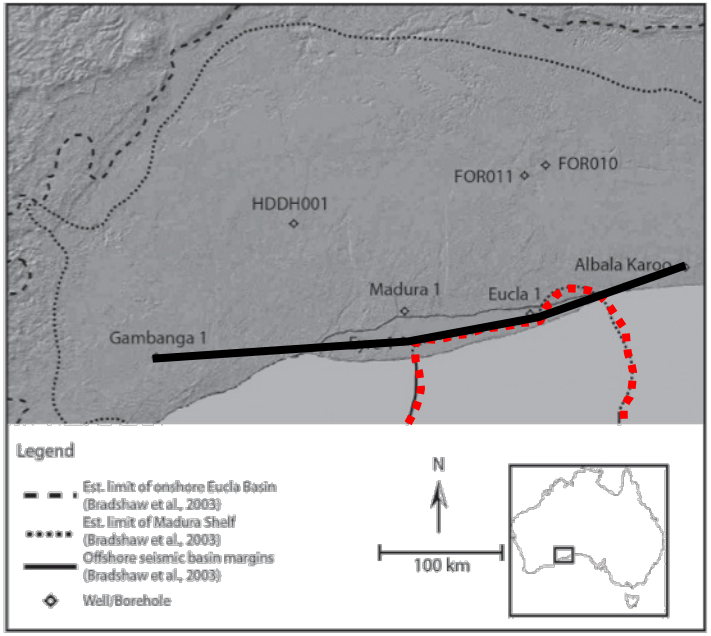
Near shore-parallel contour lines show:

- infilling of topography

and

- ~retention of original surface → largely lacking evidence for protracted hiatus and exposure in early Cenozoic (DT constraints?)



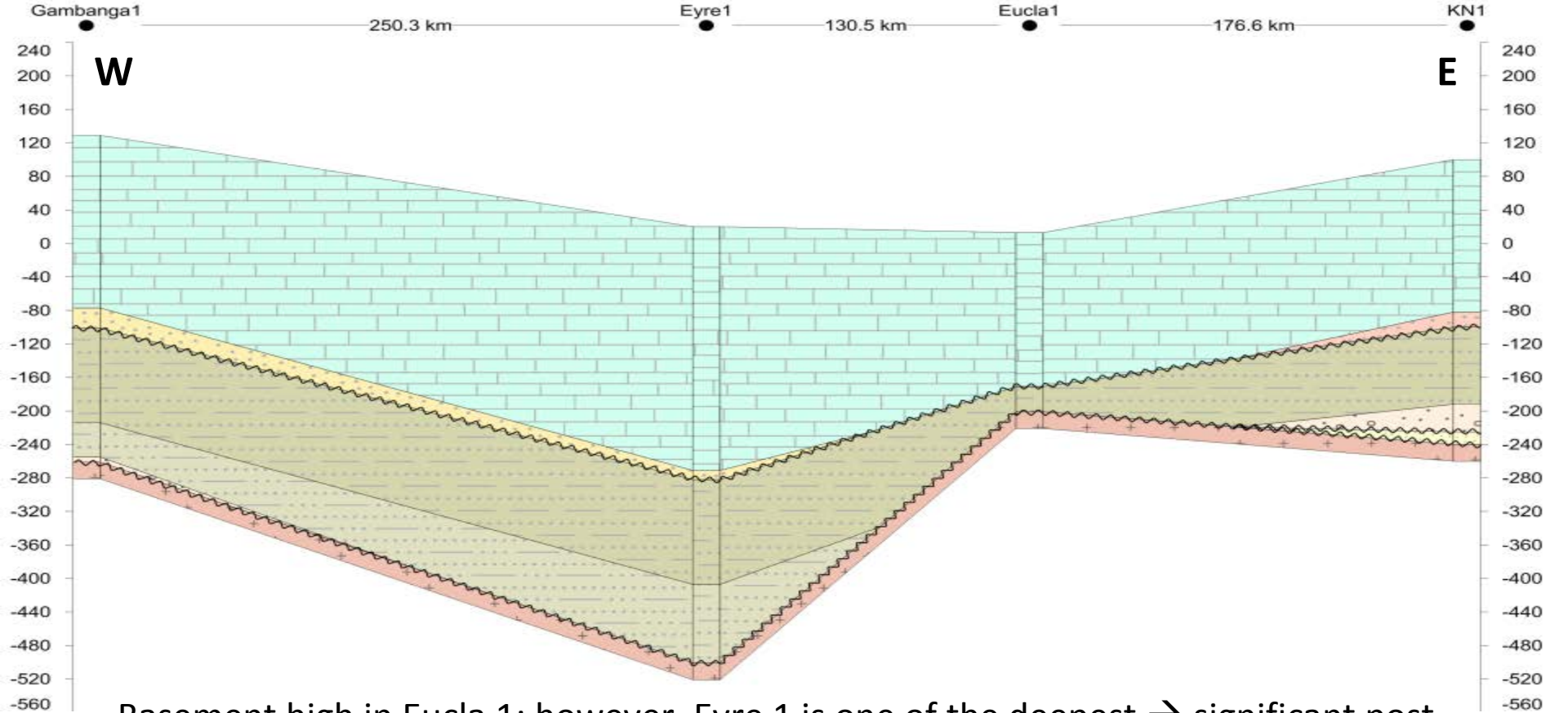


Madura Formation

Loongana Sandstone

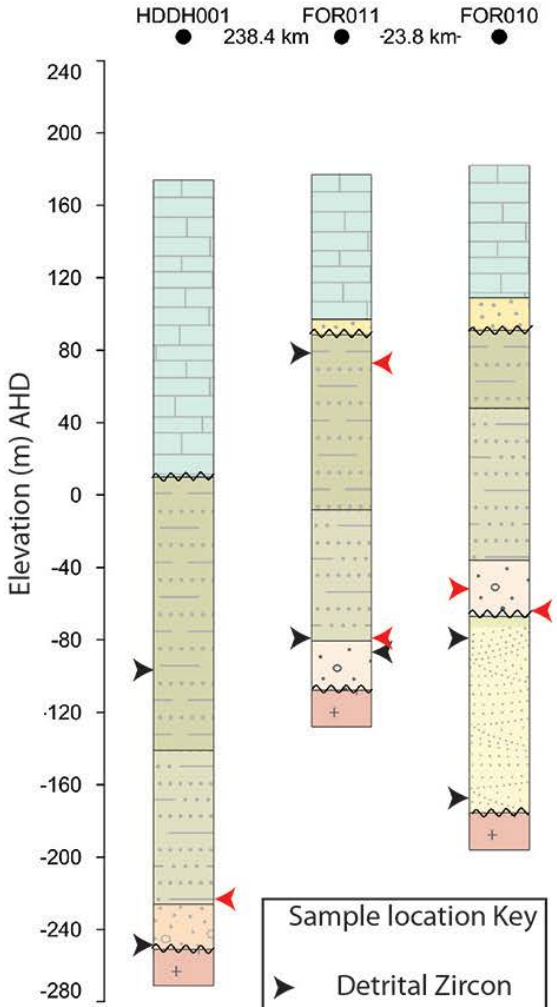
Irregular Loongana Sst. development retreated as subsidence established lacustrine conditions. Marine conditions (glauconite, micro- and macro-fossils) widespread at least by Albian.

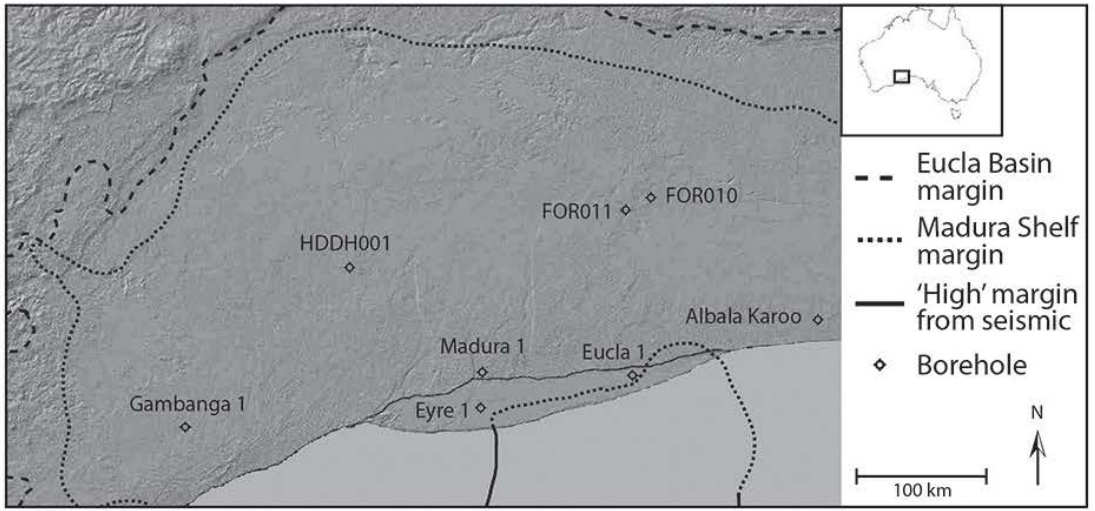
Cretaceous development of the Madura Shelf



Basement high in Eucla 1; however, Eyre 1 is one of the deepest → significant post "mechanical stage" mid-Cretaceous fault movement (*onshore grabens*)?

Sediment provenance and age constraints





Hole ID	Elv. (m)	Depth (m)	Type	GSWA #
HDDH001	-95	269	Detrital zircon	199458
HDDH001	-249	423	Detrital zircon	199456
HDDH001	-224	398	Palynology	
FOR011	79	98	Detrital zircon	199453
FOR011	-80	257	Detrital zircon	199454
FOR011	-90	267	Detrital zircon	199455
FOR011	73	104	Palynology	
FOR011	-80	257	Palynology	
FOR010	-80	262	Detrital zircon	199443
FOR010	-169	351	Detrital zircon	199444
FOR010	-54	236	Palynology	
FOR010	-62	244	Palynology	

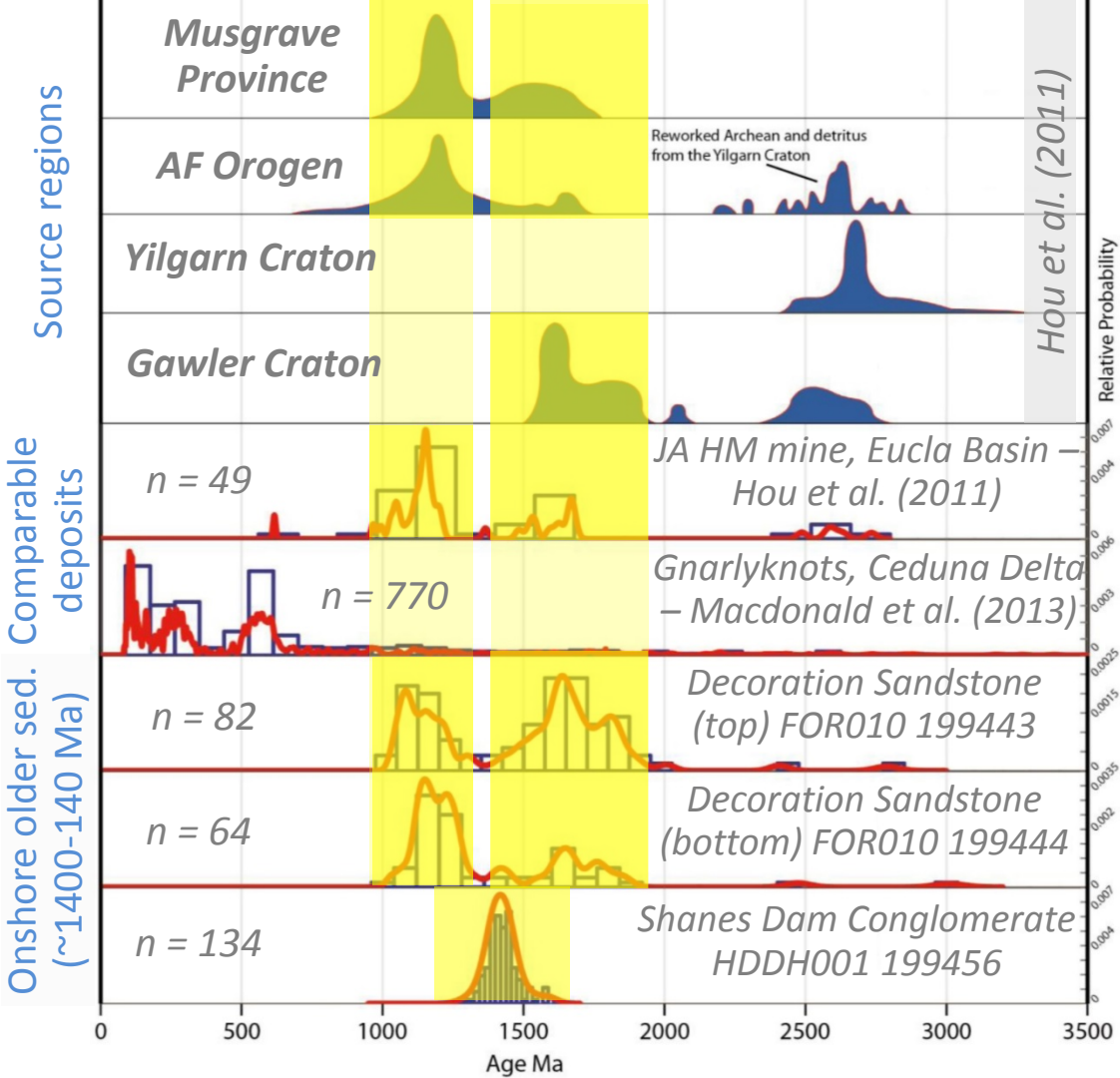
U/Pb detrital zircon age population data

Dating zircon populations **constrains sediment age** and enables **correlation to likely source regions**

Clear Musgrave and AF affinities

Older *Decoration Sandstone* partially matches seds of the Officer Basin but closely matches Cenozoic seds → relatively stable sediment sourcing?

Shanes Dam Conglomerate → local signal from Madura Province

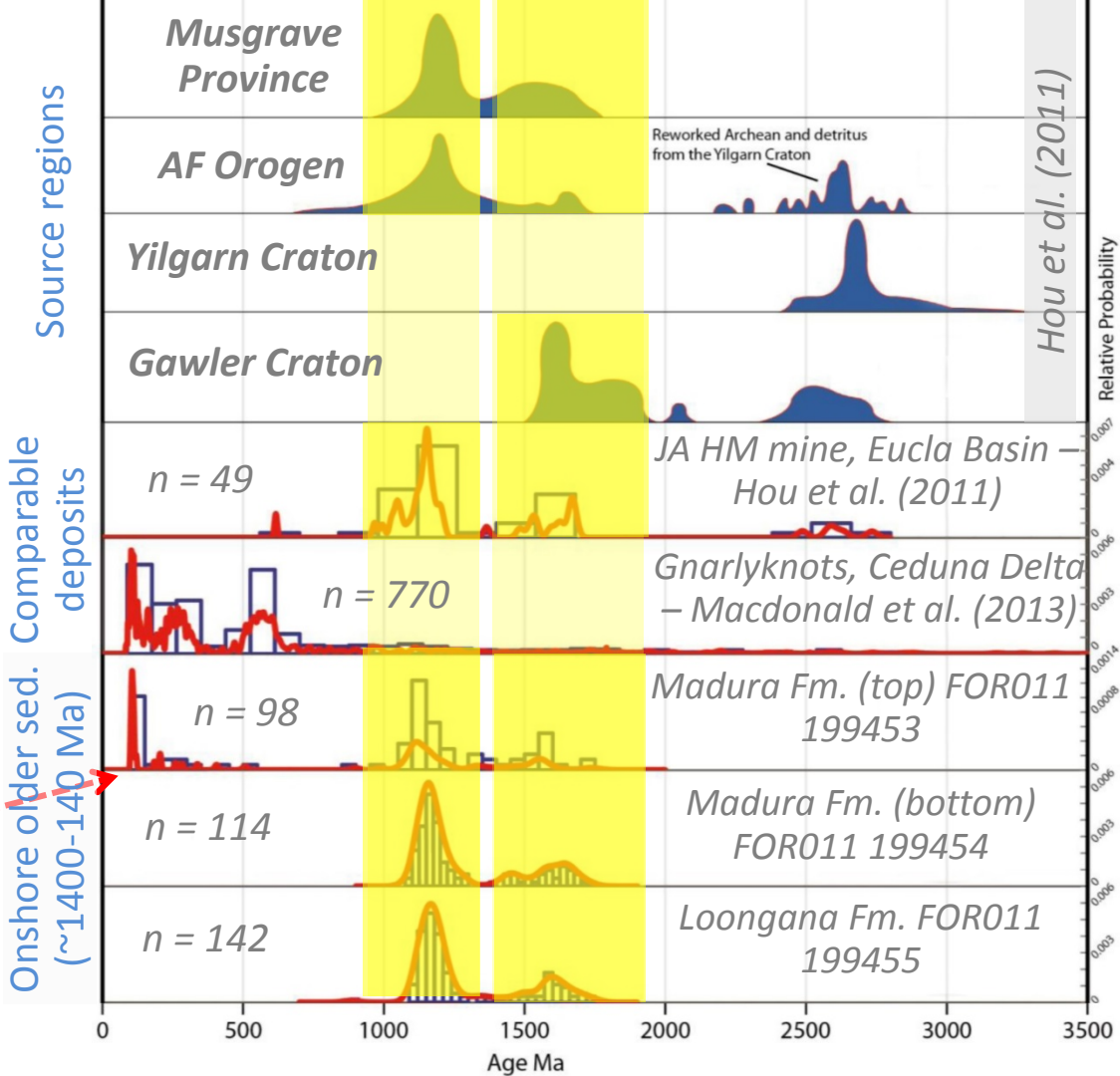


U/Pb detrital zircon age population data

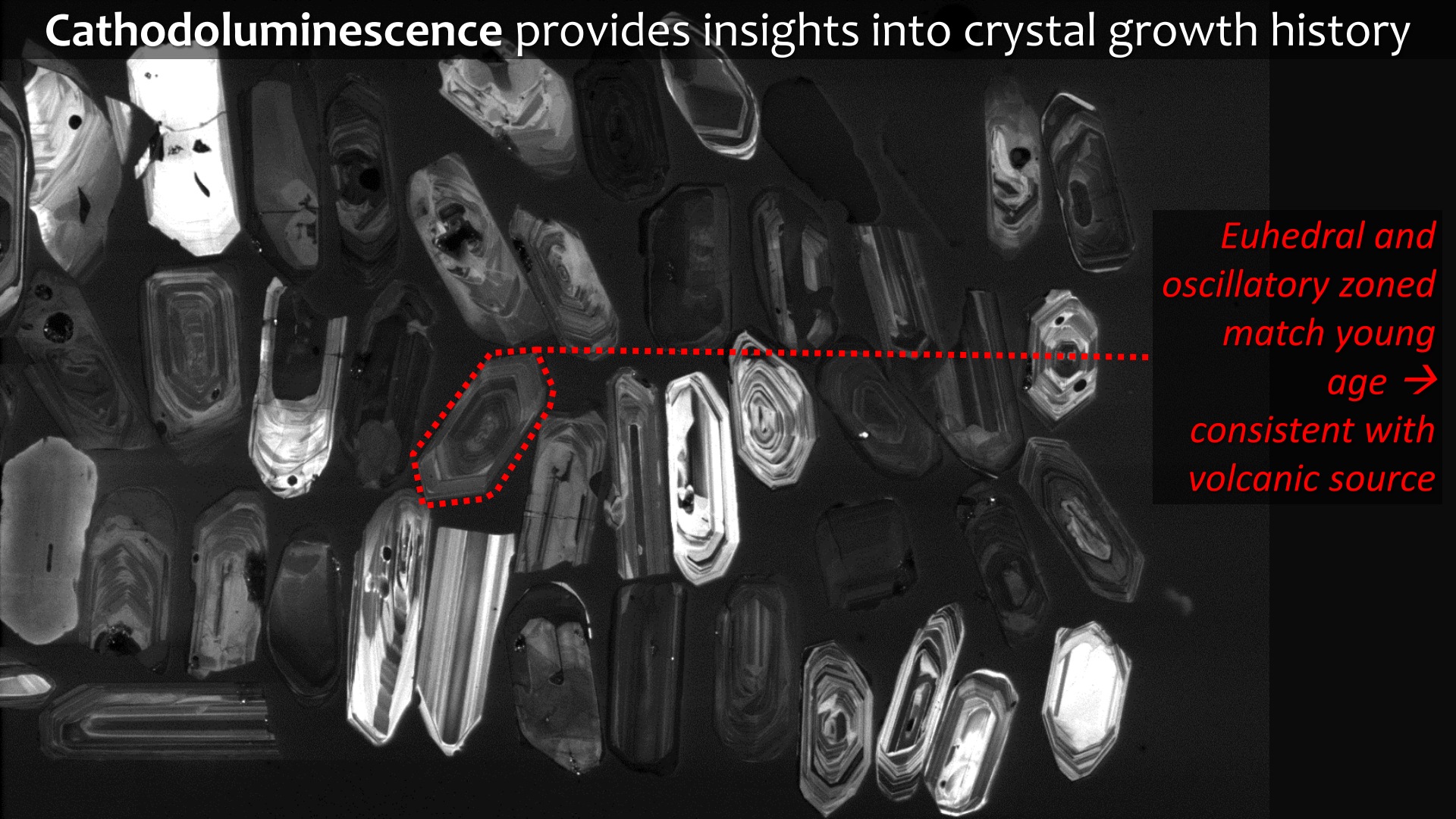
Same AF/Musgrave **sediment sources seem stable** into more recent times

East (Gnarlyknots Well) and West (the data here) are **disconnected** – missing significant Phanerozoic signal

Very young age matches dates from palynology and suggests contemporaneous **volcanic activity**



Cathodoluminescence provides insights into crystal growth history



Euhedral and oscillatory zoned match young age → consistent with volcanic source

“New” Cretaceous volcanism in west?

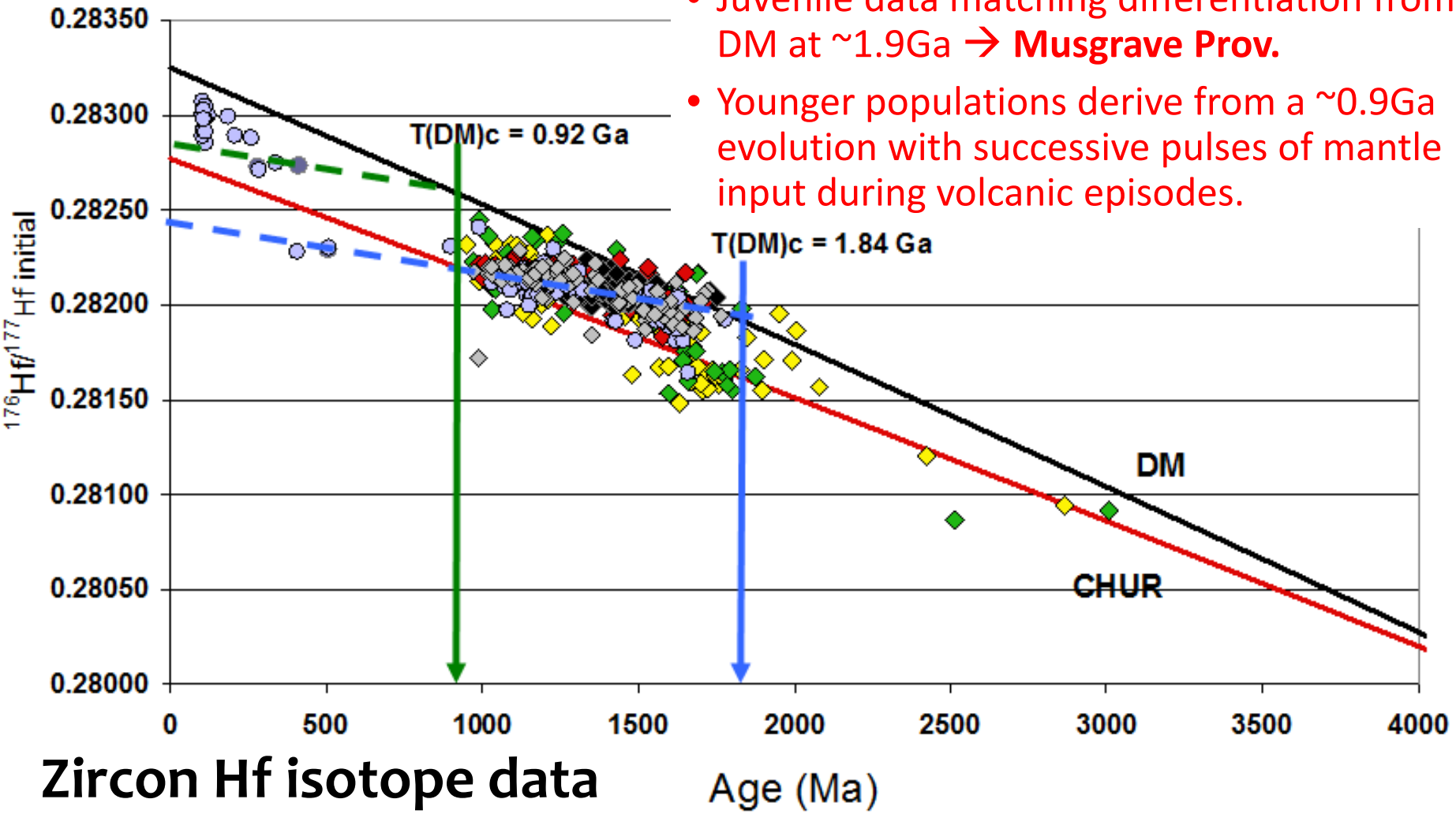
Eyre 1 core

Lapilli fragmental tuff …. **rounded breccia bombs** with cryptocrystalline selvages…bedded volcanogenic mafic ash ……quartz chlorite tuff…… ash bed… black ash ….tuff… quartz chlorite tuff…. **green chlorite tuff** ….**Tuff** …. abundant darker feather-like ash debris... ash tuff …. ash matrix…. **abundant lappilli**… psuedoporphyblastic fabric)

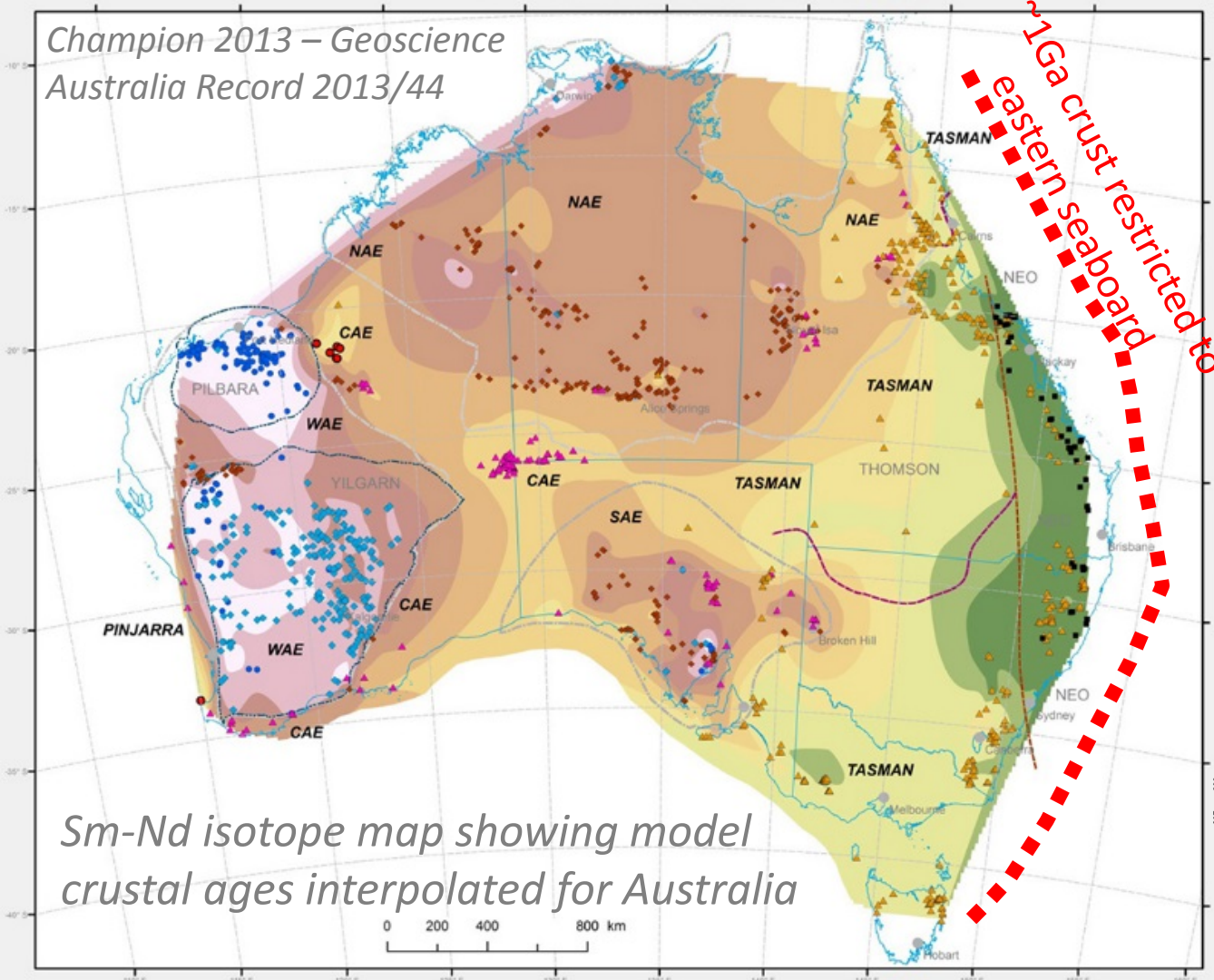
Fanciful interpretation. So where?

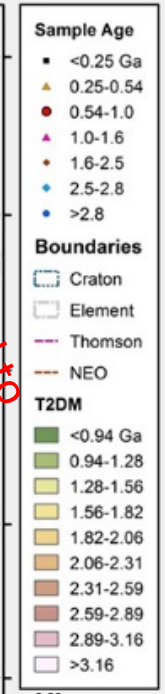
Hf data is key

- Juvenile data matching differentiation from DM at ~1.9Ga → **Musgrave Prov.**
- Younger populations derive from a ~0.9Ga evolution with successive pulses of mantle input during volcanic episodes.



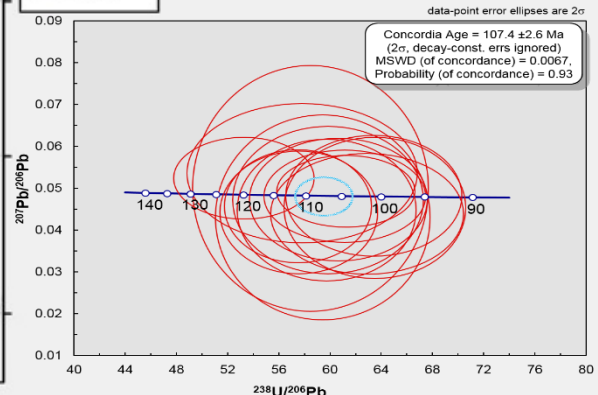
Zircon Hf isotope data





Volcanic zircons erupted 107Ma (matches Albian paly) **and were associated with ~1Ga crust**

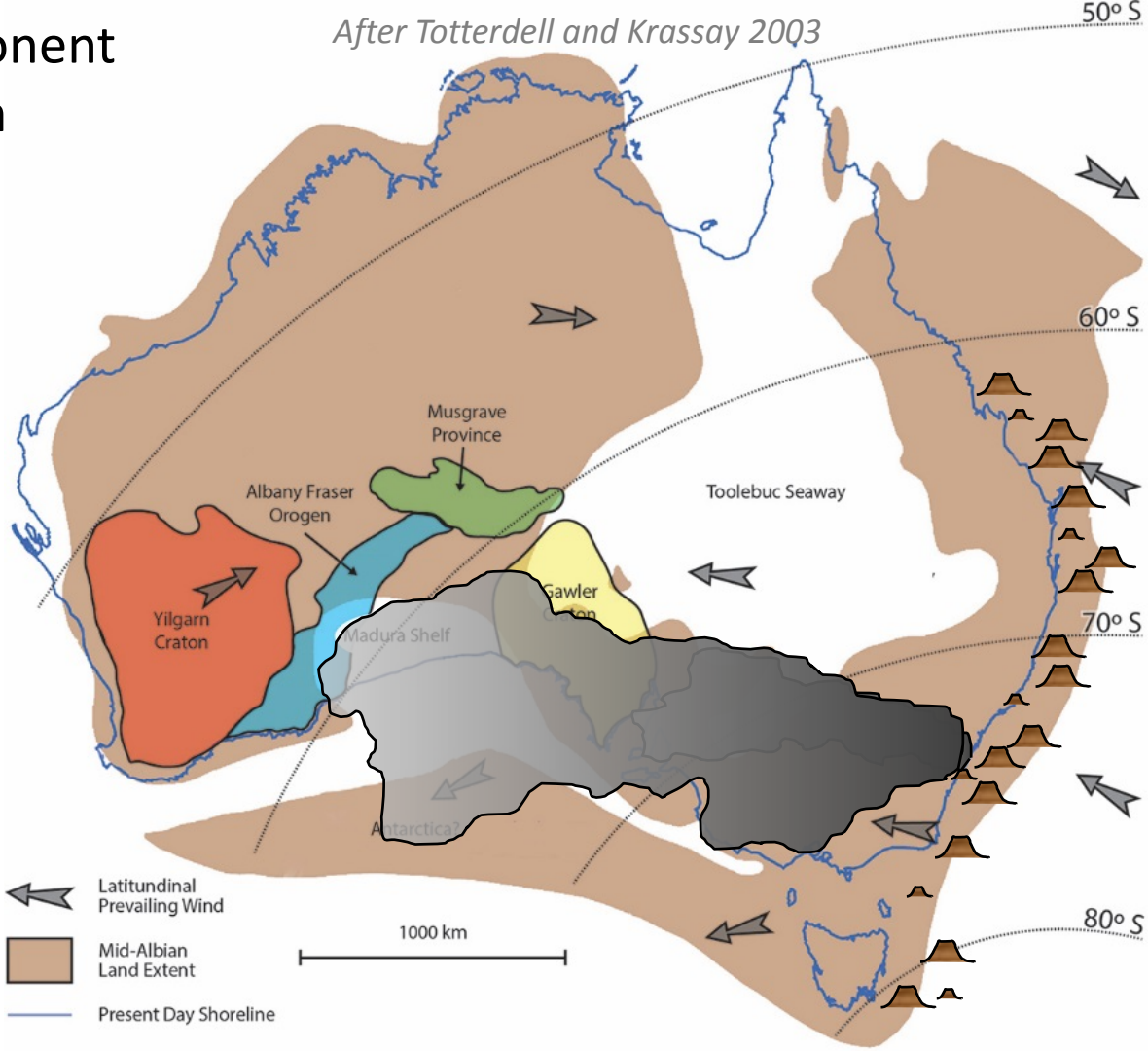
→ derived from eastern Australia



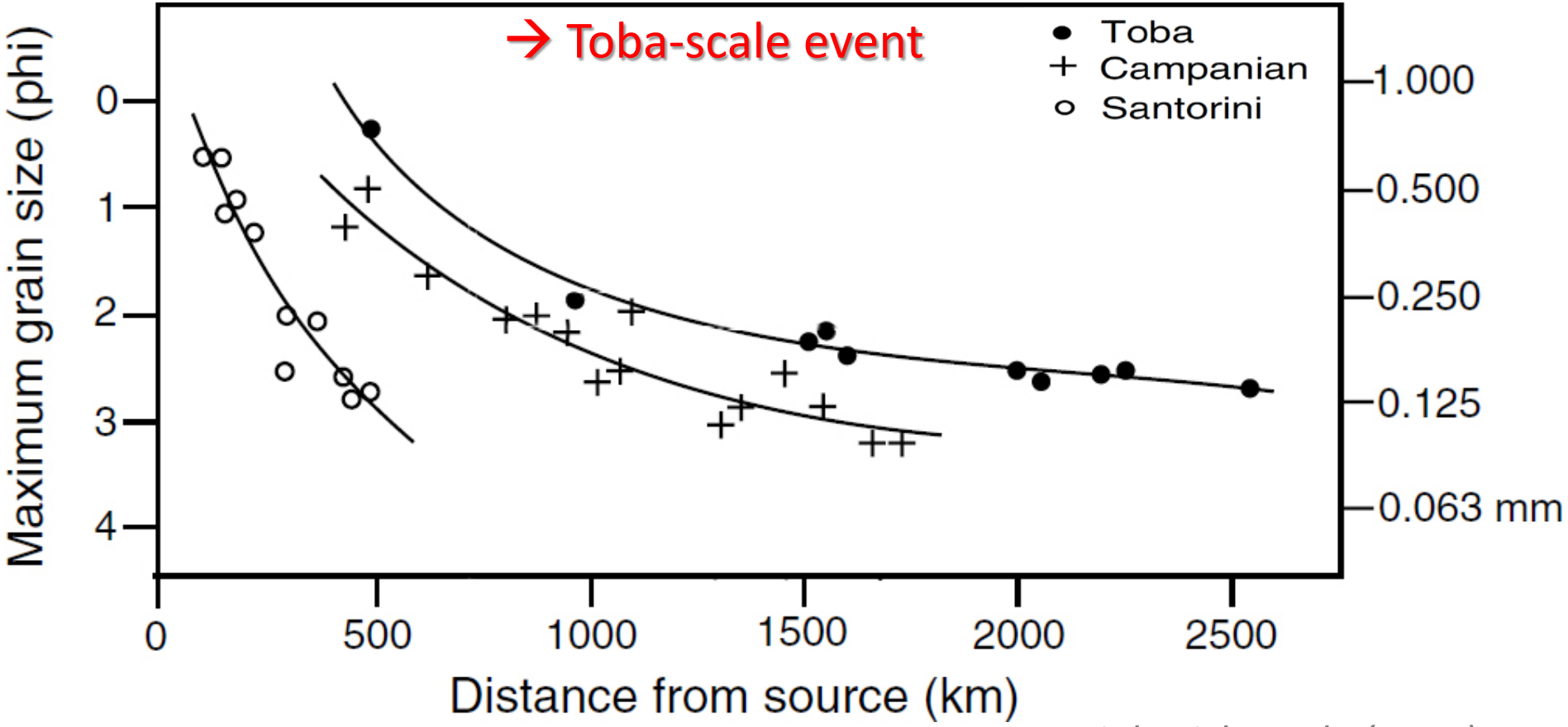
Albian zircons common component associated with SLIP volcanism producing large volumes of volcaniclastics

No evidence of any closer Antarctican sources

Palynology, CL, morphology, Hf-isotopes, missing distinct populations relative to Ceduna Sub-basin data and palaeowind **suggests super-eruption**



Super-eruption distance of travel



Ninkovich et al., (1978)

Conclusions

- GIS database of boreholes beneath Eucla established to constrain stratigraphic architecture (identify **older depocentres**) and **provide absolute constraints on DT**
- Constraining the timing of mid-Cretaceous highstand and identification of **fault movement** both of which contributed to inundation of the interior of the Madura Shelf (seismic interp)
- Musgrave Province was the likely sediment source (via multiple cycles?) for the Madura Shelf and this **routing system was stable/long-lived** (no significant changes in detrital populations)
- The Madura Shelf and Ceduna Sub-basin operated as distinct sedimentary systems → **east-west decoupling** (no "Gondwanan" signal in west)
- **~107 Ma zircon population suggest eastern SLIP super-eruptions** → absolute age constraints

- Are the wells regionally representative, or unique due to the specific magnetic targets etc?
- What are the distributions of the older sedimentary packages, when did they form, how do they influence later basin evolution?
- Where is the evidence for prolonged deposition of the Madura Fm. Or the 25-60Ma hiatus and exposure between Cretaceous and Eocene sediments?