UNRAVELLING THE MYSTERIOUS METALLOGENY OF EASTERN VICTORIA
A GEOCHEMIST'S JOURNEY

AIG MINERALS ROUND-UP, BALLARAT, VICTORIA
JUNE 18, 2026

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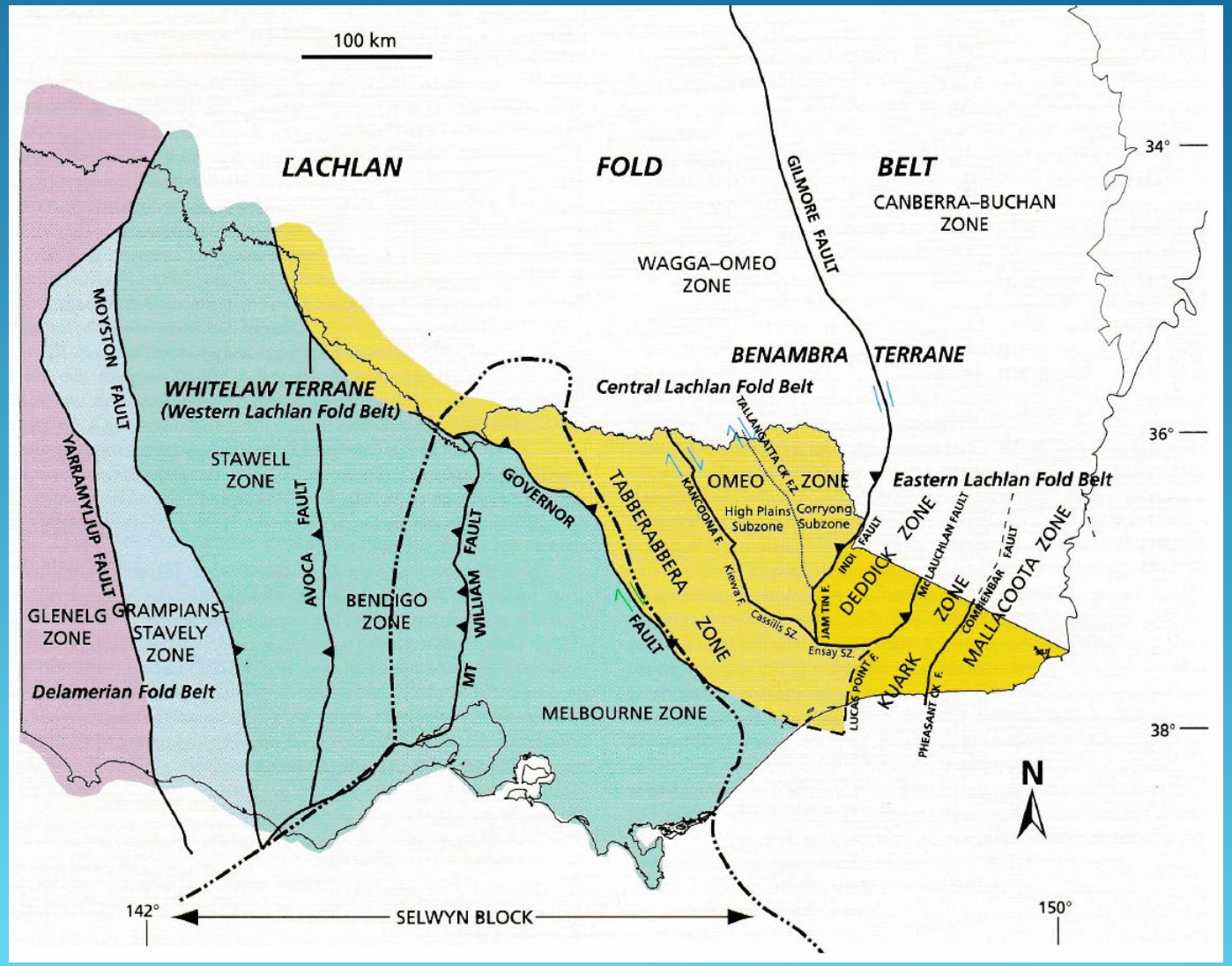
Jurassic-Cretaceous accretionary complex, Honshu, Japan

OUTLINE

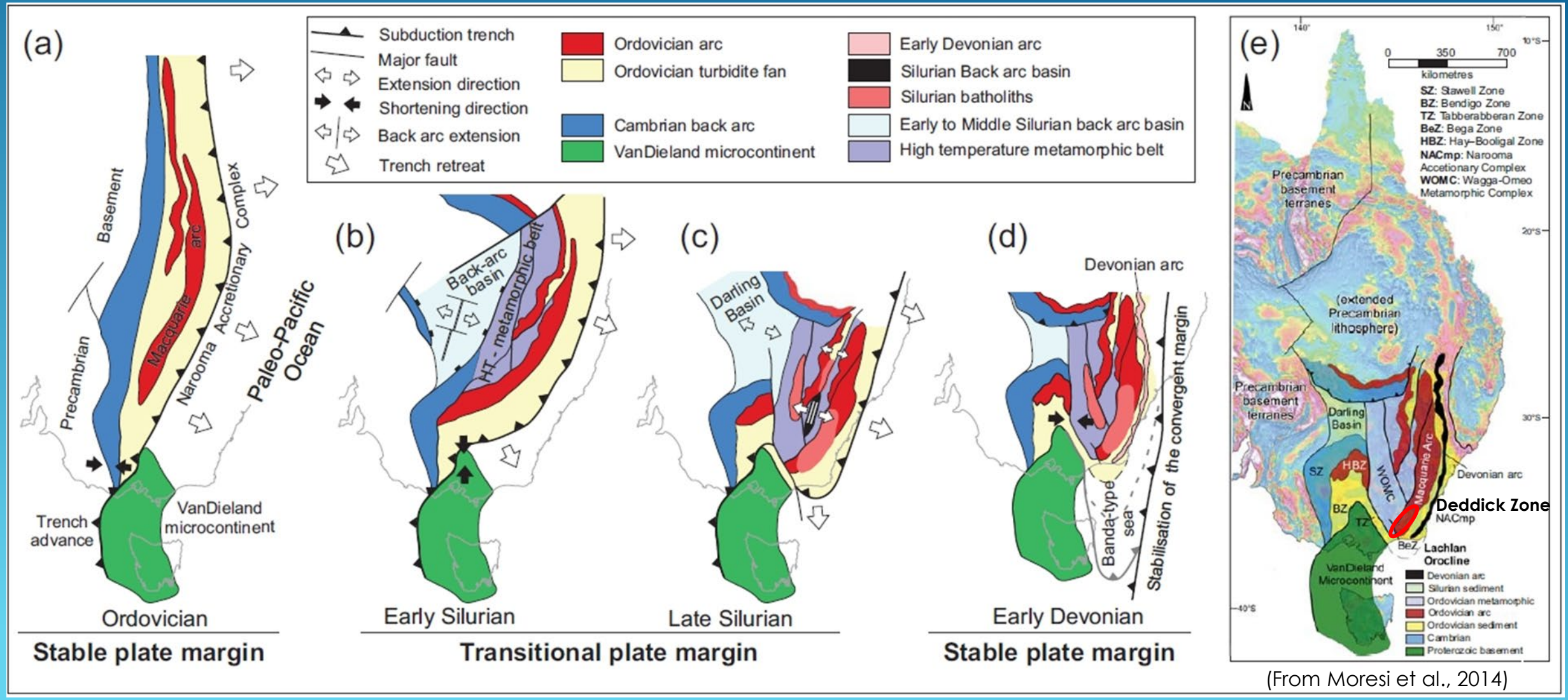
- Brief overview of tectonic model for the Lachlan Orogen
- Overview of mineral deposits in north-eastern Victoria
- Summary of timing constraints
- Metallogenesis
- What next?

STRUCTURAL ZONES OF VICTORIA



(From Birch & VandeBerg, 2003)

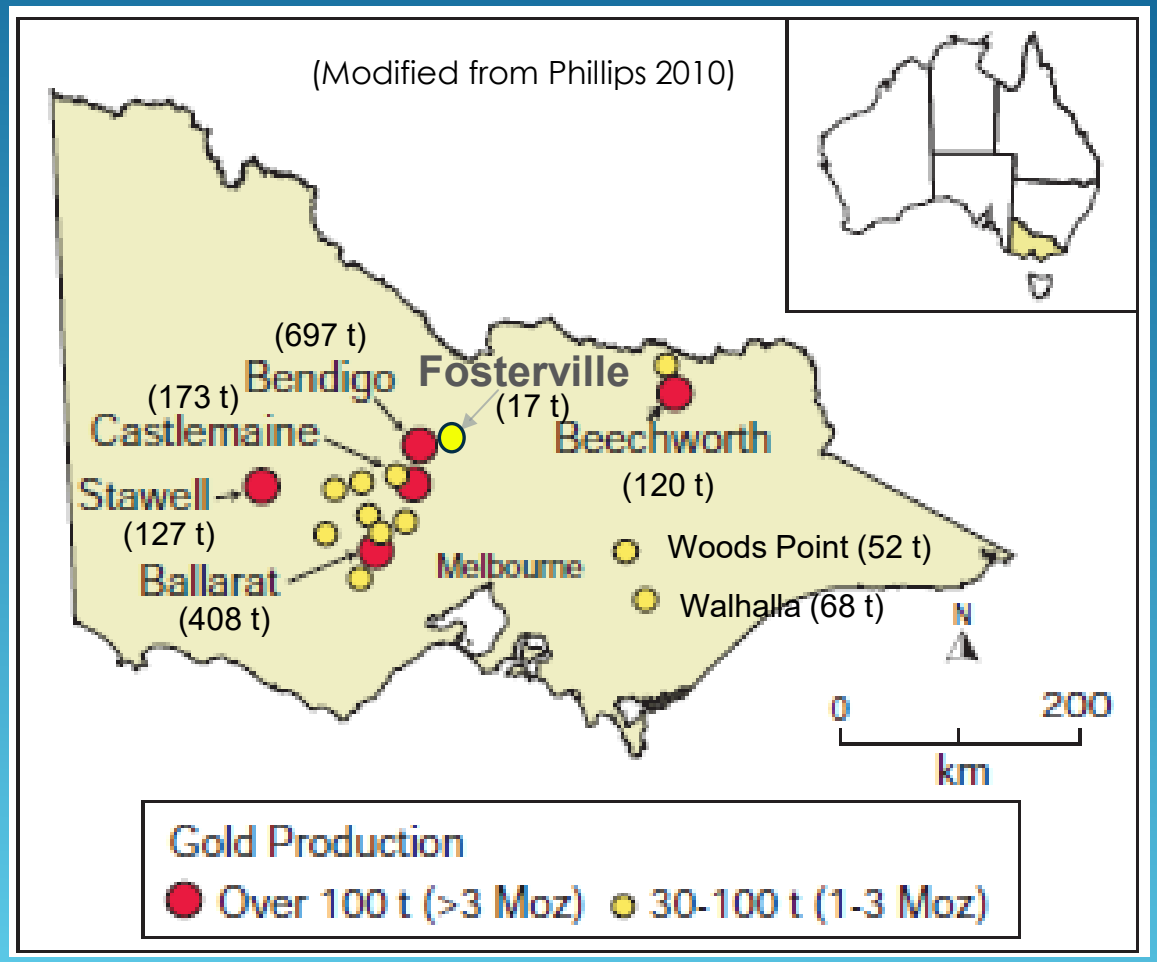
LACHLAN OROCLINE MODEL



(From Moresi et al., 2014)

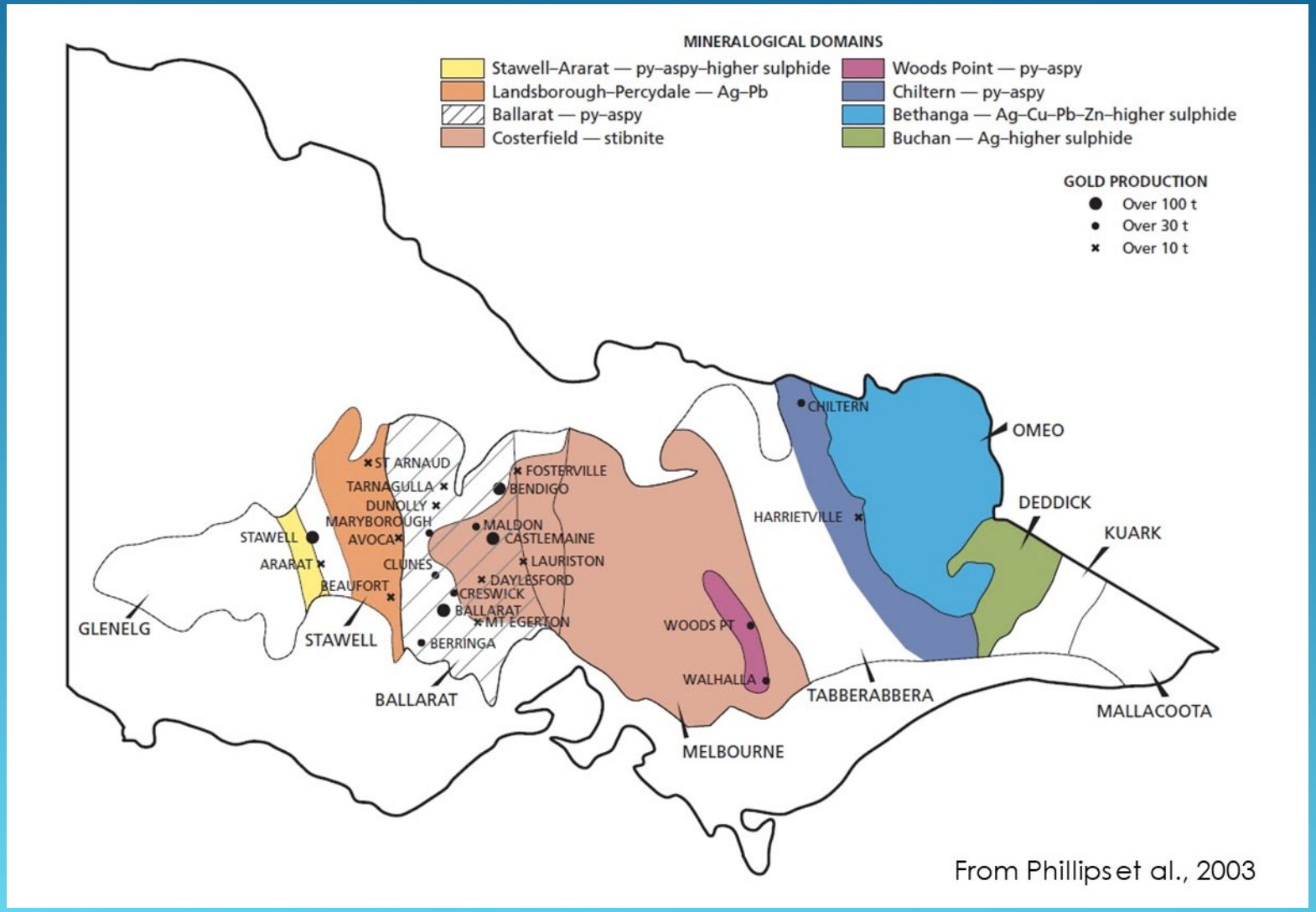
GOLD IN VICTORIA

- Most of the focus on gold in Victoria has concentrated on central Victoria.
- Beechworth was ranked 5th in terms of historical gold production at 120 tonnes by Phillips (2010) – where did this gold come from?
- Perhaps much of the gold mined in the Tabberabbera Zone found it's way through Beechworth.

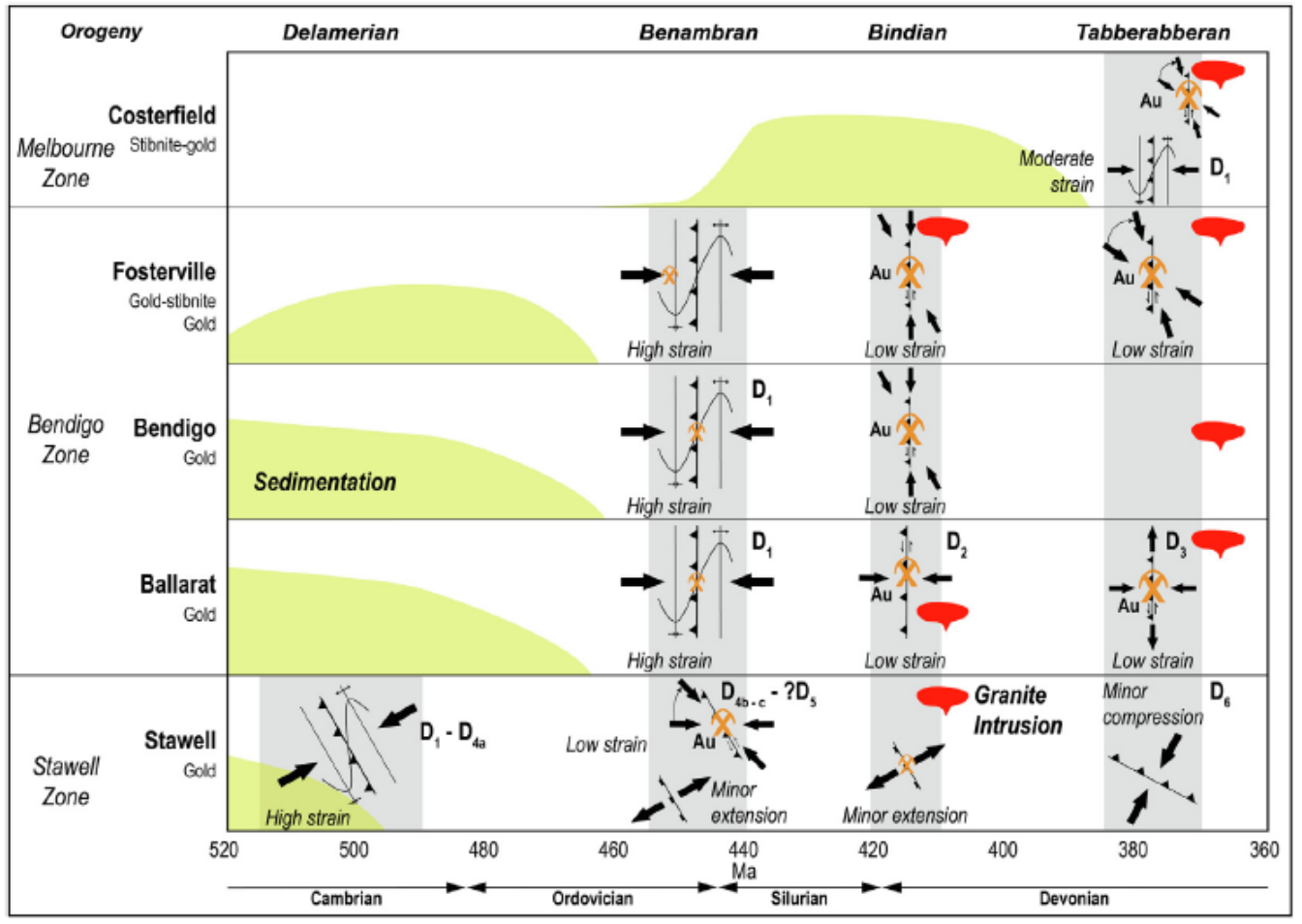


MINERALOGICAL DOMAINS

- This presentation will focus on the Chiltern Bethanga and Deddick mineralogical domains of northeastern Victoria.
- Note that the Woods Point dyke swarm has been excised from the Costerfield Stibnite Domain, although recent age constraints indicate the Au mineralization is of a similar age to that elsewhere in the Costerfield Stibnite Domain.



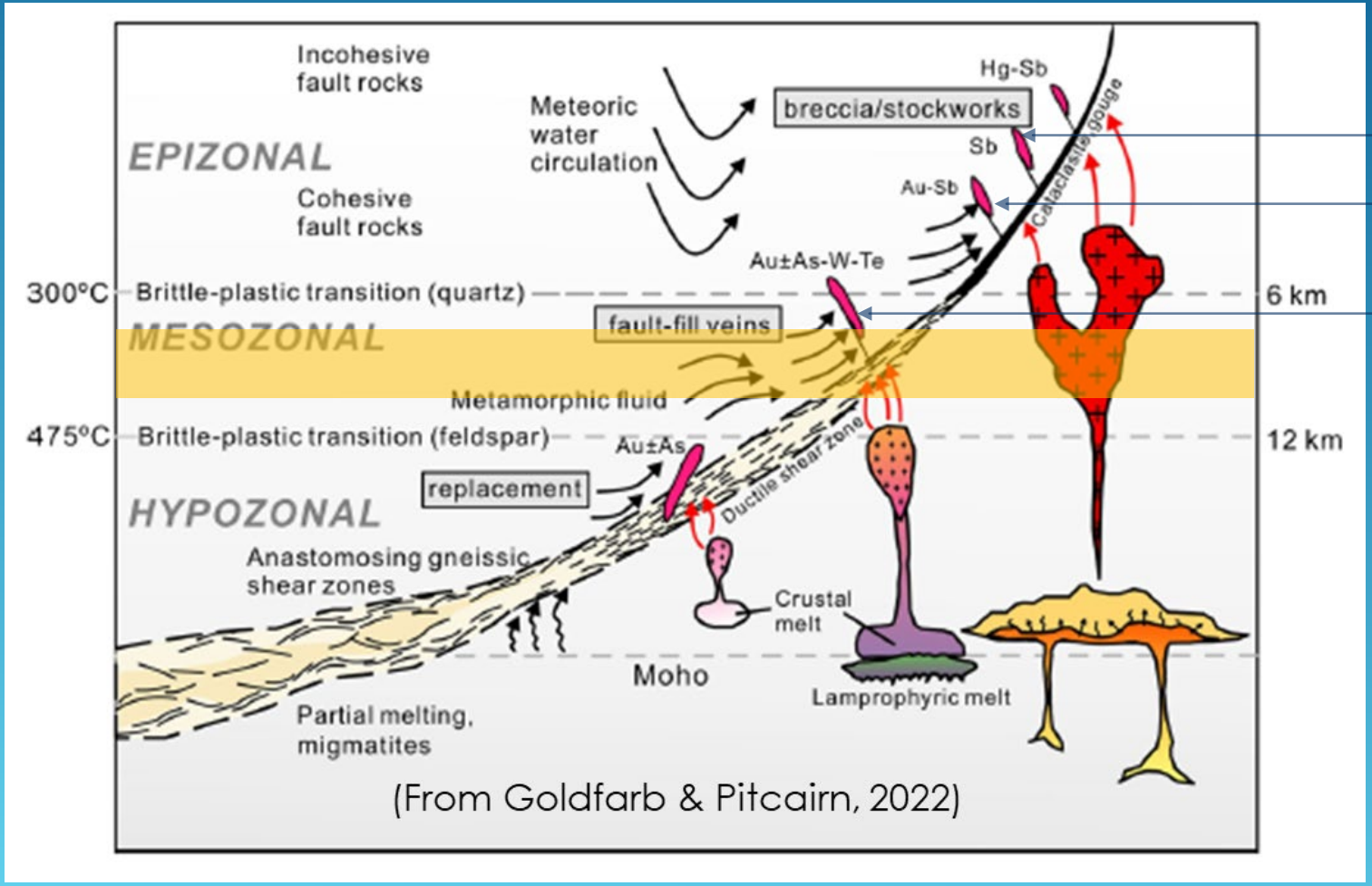
TIMING OF GOLD



- Note that multiple periods of Au mineralization and/or remobilisation are proposed within the context of a rotating stress field (Wilson et al., 2020).
- In the Melbourne Zone, hornblende $^{40}Ar/^{39}Ar$ plateau ages for the Woods Point dykes are 384.4 and 383.8 +/-6.2 Ma (Bierlein et al., 2001*), with Au mineralization at ca 376.5 and 377 +/- 6 Ma from $^{40}Ar/^{39}Ar$ plateau ages on hydrothermal sericite in quartz veins (Bierlein et al., 2001; Foster et al., 1998*), similar to the timing at Fosterville ($^{40}Ar/^{39}Ar$ age of 387.1 +/- 4.2 Ma on altered O'Dwyers Hill dyke, Bierlein et al., 2001*).
- Emplacement of mineralized dykes is pre- or syn-Tabberabberan and pre-dates post-tectonic late Devonian plutons at ca. 370 Ma (i.e. Au is associated with the earliest phase of magmatism).

* Re-calculated ages from Phillips et al., 2012

OROGENIC CONTINUUM HYBRID MODEL



Costerfield stibnite domain

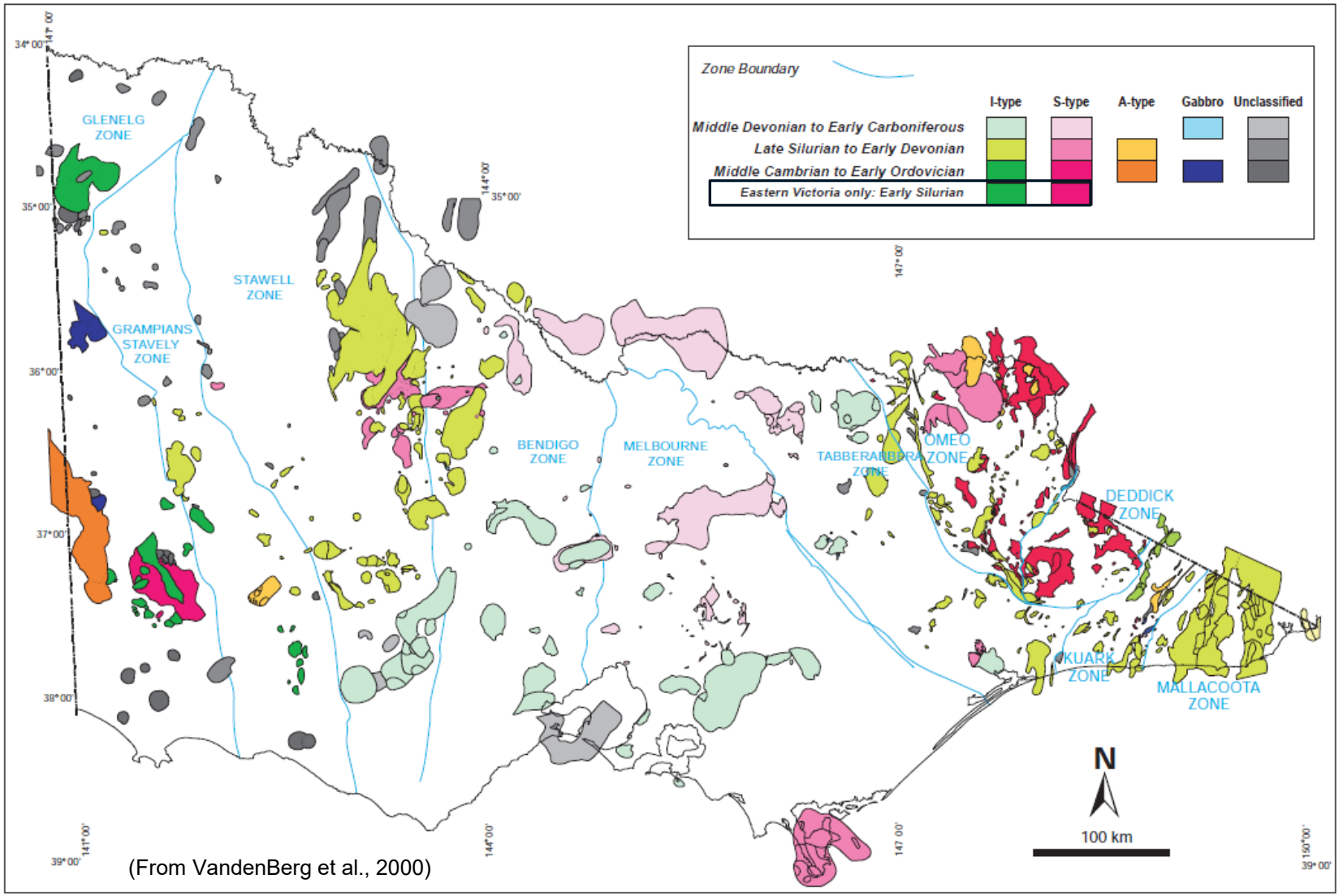
Fosterville, Costerfield (Tabberabberan)

Bendigo, Ballarat (Benambran)

Note older $^{40}Ar/^{39}Ar$ white micas ages may be preserved below mineralization temperatures of 350-400°C, depending on grain size.

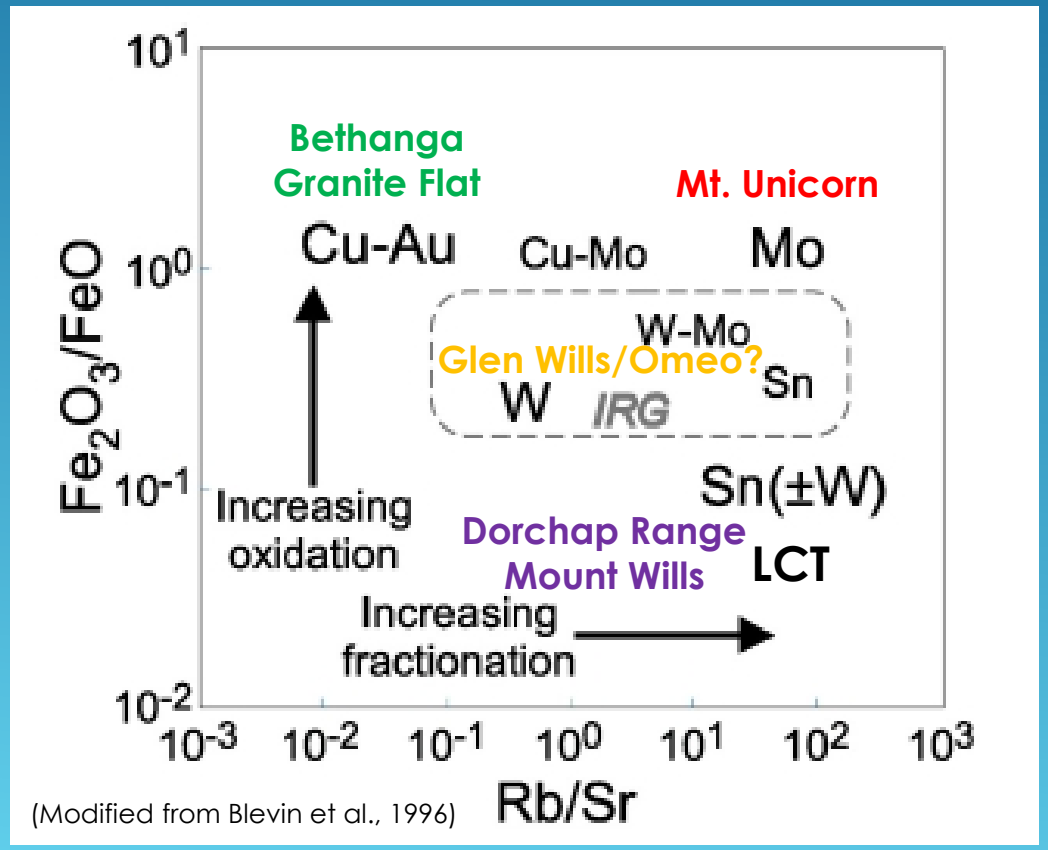
The unique aspect of the continuum model applied to central Victoria is that multiple generations of orogenic Au are proposed over a 60 myr period involving 3 orogenic events!

VICTORIAN GRANITES



- Note the mixture of Early Silurian to Late Silurian/Early Devonian I-, S- and A-type granites in eastern Victoria.
- The Deddick and northeast Omeo Zones are inferred to contain mainly early Silurian S-type granites produced by partial melting during the Benambran Orogeny.

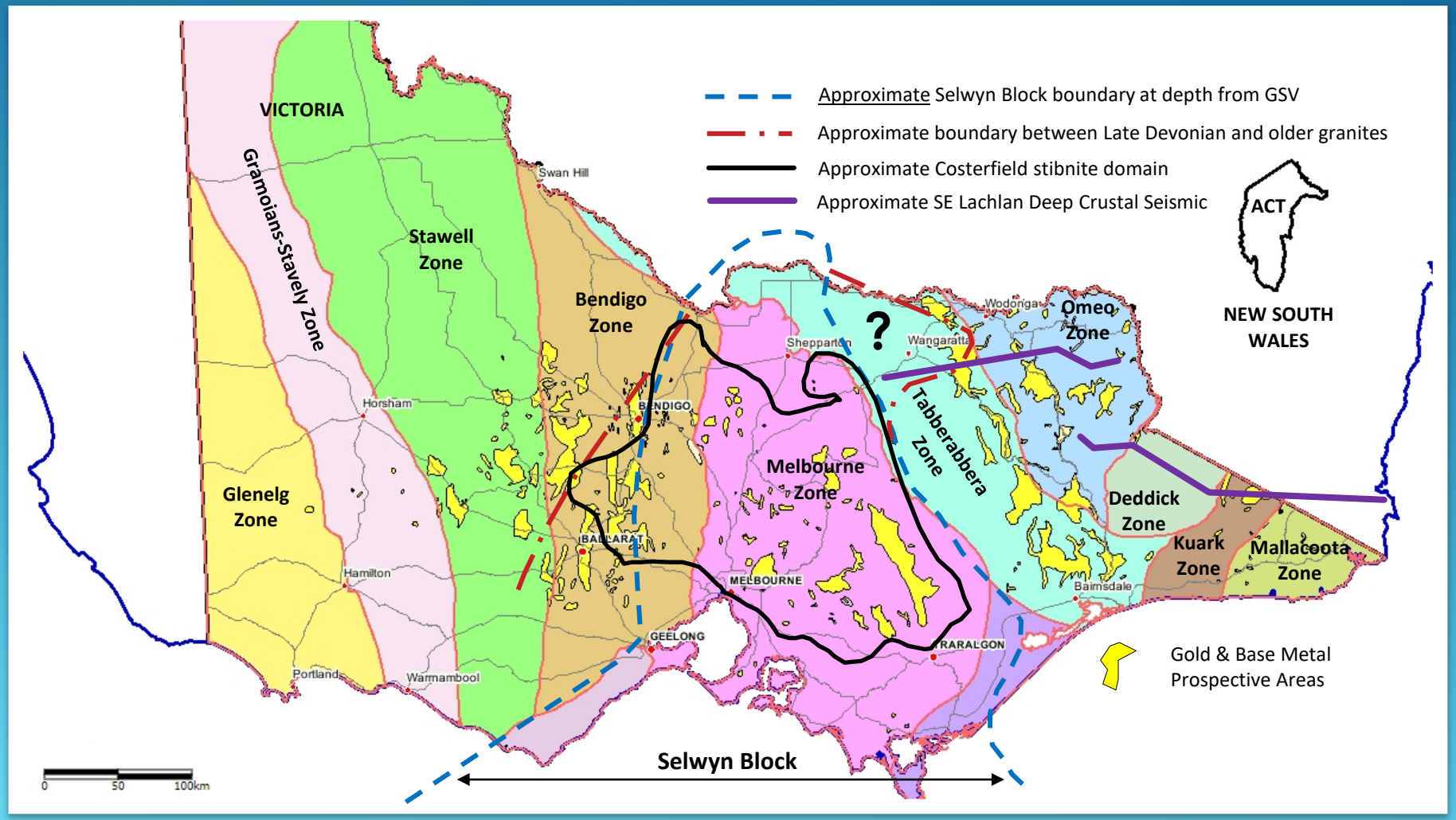
MAGMATIC HYDROTHERMAL SYSTEMS



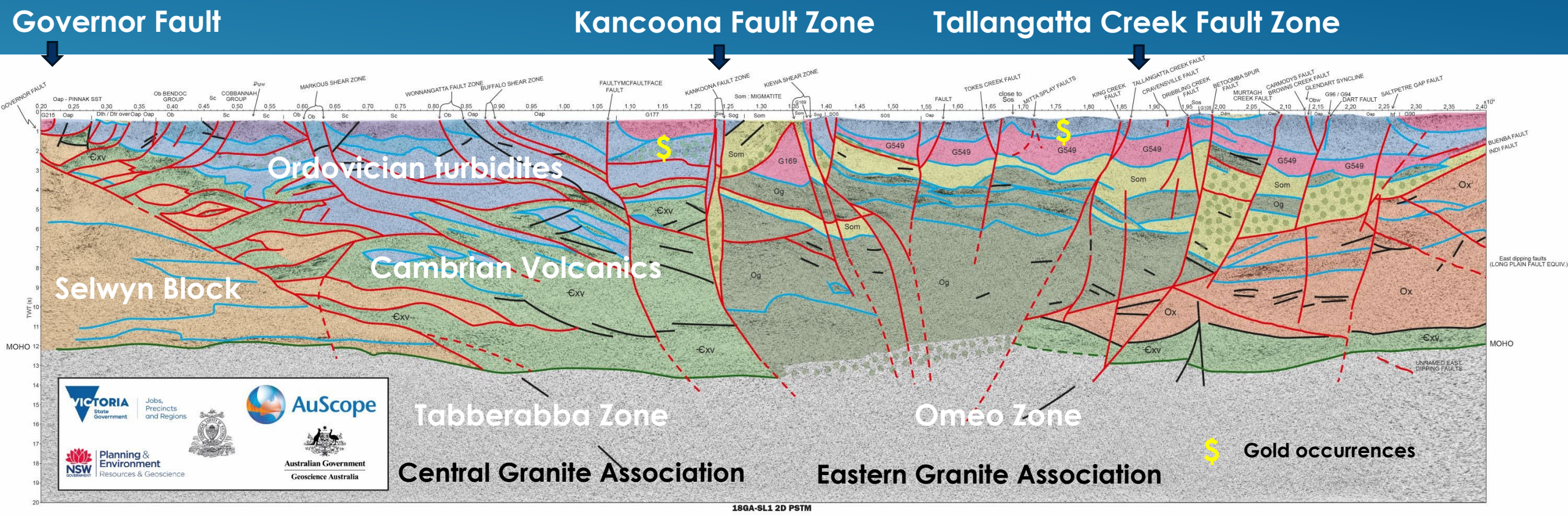
(Modified from Blevin et al., 1996)

- **Magmas associated with porphyry Cu-Au systems are:**
  - Oxidised to strongly oxidised (magnetite series)
  - Poorly evolved, primitive melts (K/Rb ratio >250)
  - Poorly fractionated (Rb/Sr ratio <1)
  - Typically, hydrous with Sr/Y ratios >40 (hornblende)
  - I-type metaluminous (Al<(Ca+Na+K))
- **Magmas associated with Sn and LCT pegmatites are:**
  - Strongly reduced
  - Highly fractionated (Rb/Sr >10)
  - Strongly evolved (K/Rb ratio <100)
  - Peraluminous, generally S-type (Al>(Ca+Na+K))

BRINGING IT ALL TOGETHER…..

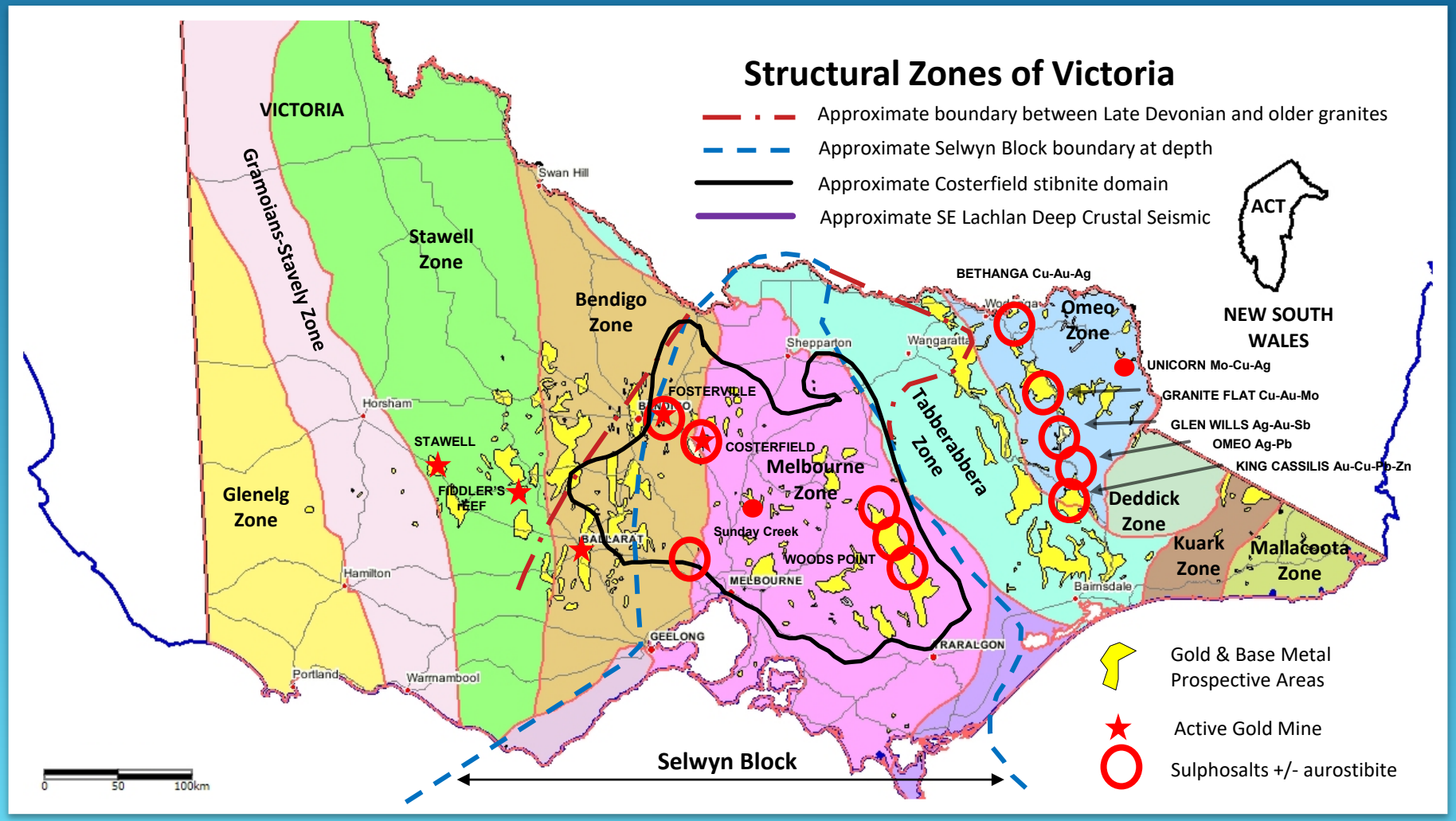


SE LACHLAN DEEP CRUSTAL SEISMIC REFLECTION SURVEY



There is a major structural discontinuity at the boundary between the Tabberabba and Omeo Zones (i.e. the Kanccona Fault Zone) that corresponds to the boundary between the Central and Eastern Granite associations in the northern Tabberabbera Zone based on $^{87}Sr/^{86}Sr$ ratios of Gray (1990).

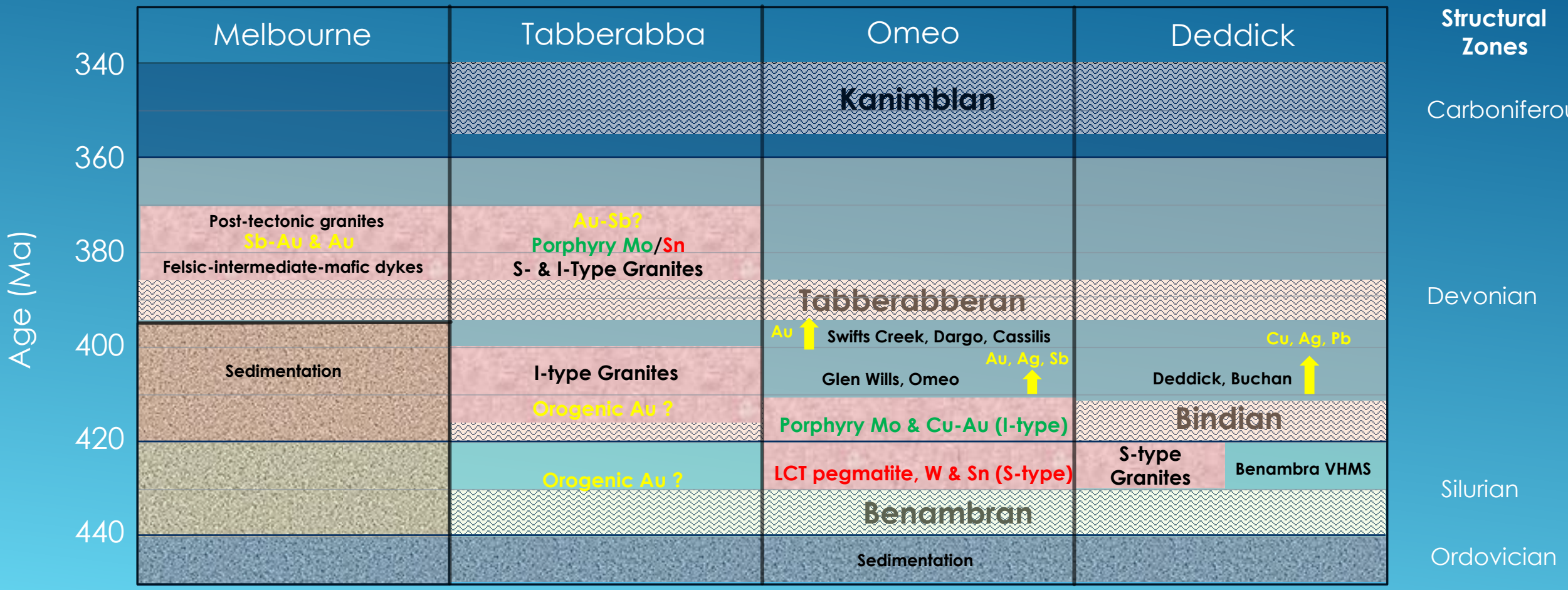
GOLD DEPOSITS WITH SULPHOSALTS



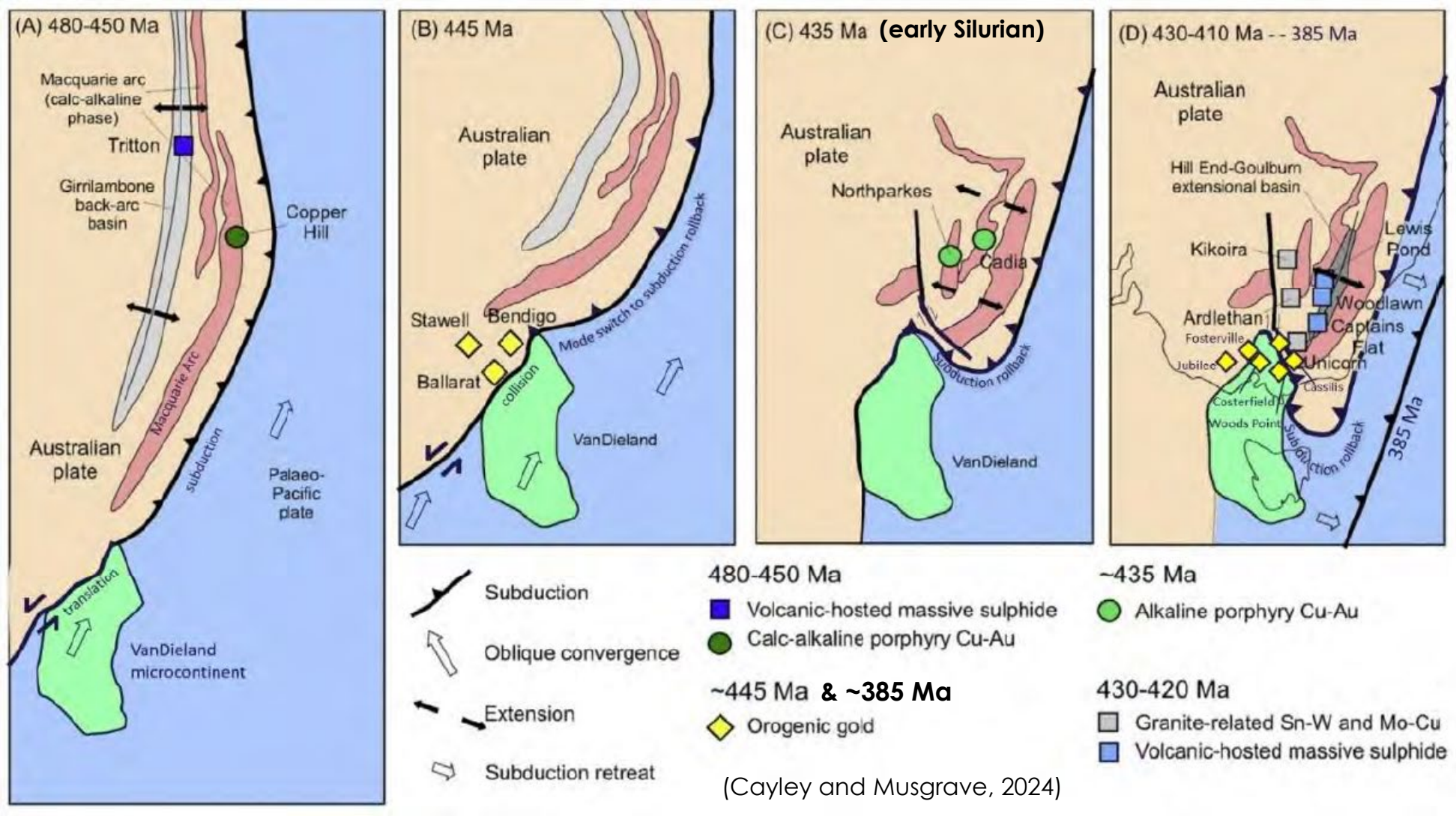
TIMING OF MINERALIZATION

- Orogenic Au in the Tabberabbera Zone hosted by Ordovician turbidites predates early and late Devonian granites.
- Sn & W in the northern Omeo Zone at ~435-426 Ma (cassiterite & wolframite U-Pb ages; Waugh et al., 2024).
- Late Silurian magmatism in the Deddick Zone, including volcanism and VHMS in the Limestone Creek Graben.
- Au-Ag-Sb intrusion-related (?) mineralization at Glen Wills & Sunnyside post-dates emplacement of the Mounts Wills S-type granite & Sn/LCT pegmatites at 420 +/- 4 Ma (U-Pb monazite age from Sn-LCT pegmatite; Eagle et al., 2015).
- Granite Flat magmatic-hydrothermal Au-Cu-Bi-Ag mineralization at 414 +/-2 Ma (Re-Os molybdenite; Waugh et al., 2024) in the Banimboola Quartz Monzodiorite (U-Pb zircon 412.6 +/- 2.9 Ma; Mole et al.) (i.e. coeval).
  - Mo-Cu-Ag mineralization in the Mount Unicorn Porphyry also emplaced at 412 +/- 2 Ma Re-Os molybdenite; Huston et al., 2022).
- Ag-Pb, Ag-Au and Cu epithermal (?) occurrences post-date early Silurian to early Devonian granites at Deddick and Omeo, respectively, and Pb-Ag-Zn-Cu occurrences post-date the lower Devonian Buchan Caves Limestone.
- Swifts Creek goldfield younger than the Swifts Creek Igneous Complex, emplaced in the early Devonian (408 +/- 4 & 402 +/- 4 Ma (Rb-Sr biotite ages, Eberz, 1987).
  - Au-Ag-Pb-Zn mineralization at Cassilis post-dates late Silurian/early Devonian Cassilis Shear Zone and has $^{40}Ar/^{39}Ar$ age on hydrothermal muscovite of 401 +/- 3 Ma (Phillips et al., 2003); Mammoth Lode porphyry 402 +/- 7 Ma (U-Pb zircon, Arne et al., 1996).
- Dargo goldfield younger than I-type granites (397 +/- 11 Ma K-Ar biotite/hornblende, Richards & Singleton, 1981).
- Porphyry Mo mineralization in the Everton granodiorite is 380 +/- 2 Ma (Re-Os molybdenite; Huston et al., 2022).

METALLOGENIC CONSTRAINTS



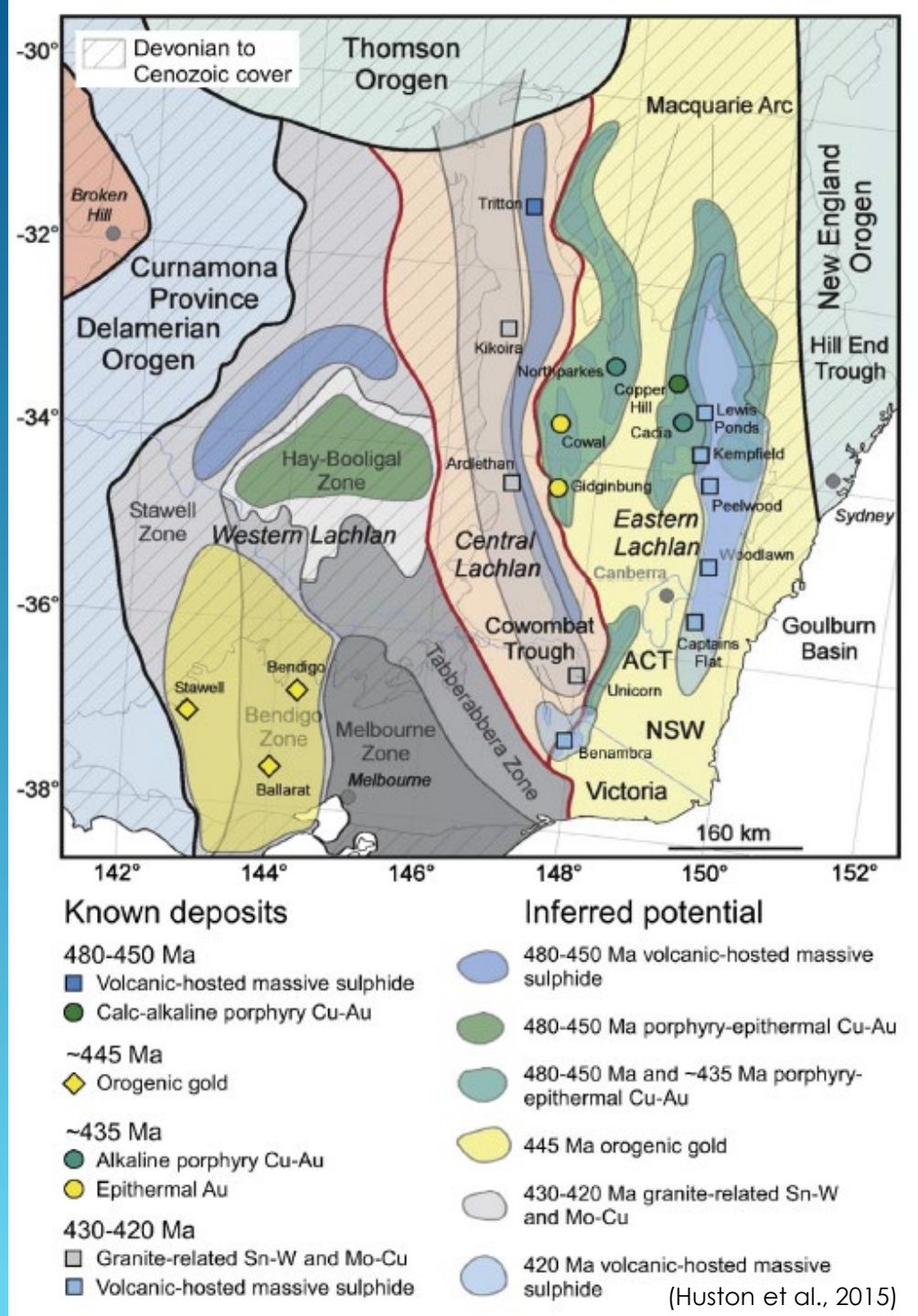
OROCLINE MODEL WITH MINERAL DEPOSITS



(Cayley and Musgrave, 2024)

METALLOGENIC PROVINCES

- Presence of Benambran-aged orogenic Au in the eastern Tabberabbera Zone interpreted structurally but not confirmed by geochronology.
- No evidence for the Ordovician to early Silurian VHMS or calc-alkaline porphyry Cu-Au/epithermal metallogenic provinces extending south into Victoria.
- Early- to mid-Silurian S-type granites (Sn, W, Li), late Silurian VHMS and early Devonian I-type Cu-Au, Mo & W.
- Mid to late Devonian Mo & Sn present in the northern Tabberabbera Zone.



(Huston et al., 2015)

WHERE TO NEXT?

- U-Pb geochronology of key igneous rocks throughout eastern Victoria; there is still too much reliance on unreliable K-Ar ages published in 1981, as good as that work was at the time.
- Modern ore deposit studies of the various mineral occurrences (e.g. Glen Wills, Dargo, Tabberabbera Au deposits, Deddick, Bethanga, Omeo).
- Further geochronology on the timing of mineralization integrated with structural, textural and paragenetic studies using a variety of methods (e.g. U-Pb zircon ages of intrusive rocks with cross-cutting relationships, $^{40}Ar/^{39}Ar$ analysis of potassic alteration minerals **in a regional context**, Re-Os geochronology on sulphide minerals).
  - Many $^{40}Ar/^{39}Ar$ analyses in the Omeo Zone may reflect regional cooling/exhumation
- More mapping to establish cross-cutting relationships in the field and to integrate relative timing relationships into the regional structural history.
- The above would contribute to a mineral systems approach to exploration.

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