THE GIANT LACHLAN OROCLINE OF EASTERN AUSTRALIA –

A rAdiCaL NEW WAY OF THINKING ABOUT THE ORDOVICIAN-DEVONIAN TECTONICS AND MINERAL SYSTEMS OF EASTERN AUSTRALIA

R. A. Cayley*, R. J. Musgrave,

*Geological Survey of Victoria (Resources Victoria)

Key Words: Lachlan Orocline, Lachlan Orogen, geodynamics, accretionary orogen, mineral systems, Macquarie Arc, Selwyn Block, Vandieland.

INTRODUCTION

The Lachlan Orocline hypothesis (Cayley & Musgrave, in prep.) is a geodynamic model for the Early Palaeozoic evolution of the Australian Continent proposed by Cayley (2010, 2012) that advocates for the presence of a huge (hundreds of kilometre amplitude) Silurian-aged Z-shaped, vertically plunging megafold – the Lachlan Orocline – superimposed over a previously linear and relatively simple Ordovician Lachlan Fold Belt (LFB) suprasubduction-accretion system developed above a single, continent-dipping subduction zone that had formed parallel to the eastern edge of Gondwana. The Ordovician suprasubduction system included the Macquarie Arc (Crawford et al., 2007; Glen et al., 2007) built, in part at least, on a substrate of thin Early-Mid Cambrian MORB to intraoceanic arc/backarc crust that crops out widely in Victoria (Crawford, 1988; Squire et al, 2006), was largely not involved in Delamerian orogenesis (VandenBerg, 1991, VandenBerg et al., 2000) and instead lay undeformed in a deep marine proto-LFB Paleopacific setting into the Ordovician.

The origins of the Lachlan Orocline model lie in the quest for a single unifying geodynamic scenario able to rationally explain the plethora of apparently contradictory fundamental geological (and particularly paleogeographic) constraints long recognised and well documented in the Early Palaeozoic geology of Eastern Australia, and well documented in Victoria in particular.

THE LACHLAN OROCLINE HYPOTHESIS

The Lachlan Orocline model is a development – effectively a simplification – of the multiple, coeval divergent subduction zone hypothesis proposed by Gray & Foster (1998) for the same region for the southern LFB. Their model includes a central distinctly separate east-dipping subduction zone.

Rather than advocating for three separate but broadly coeval subduction zones in an oceanic environment to explain the observed distribution of Ordovician arc rocks and observed coeval accretionary wedge symmetries in Victoria in particular (and possibly Tasmania – eg. Reed, 2001), the Lachlan Orocline model proposes that the westernmost west-dipping subduction zone of the Gray & Foster (1998) model was not active post-Cambrian (Cayley et al., 2011; 2018) with Ordovician-Devonian 'western' Lachlan Fold Belt deformation instead attributed to intraplate processes, and reinterprets the 'central' east-dipping subduction zone of Gray & Foster (1998) as the southernmost part of their easternmost west-dipping subduction zone, but reoriented in the central limb of the superimposed Lachlan Orocline megafold.

The near-contiguous limbs of the Lachlan Orocline occur in Ordovician deep marine siliciclasitic rocks, including rocks in eastern Victoria that preserve characteristics of syn-sedimentary deformation in an accretionary wedge setting. The orocline limbs are exposed near-continuously across the east-west trending portion of the southern Great Dividing Range, which extends from the easternmost Delamerian Orogen in western Victoria across the full width of the LFB to the east coast of Australia.

Behind (ie north-of) the near-contiguous orocline limbs, field relationships exposed in Victoria, which can be extended into NSW with confidence using geophysics, and paleomagnetic data, all show that Ordovician Macquarie Arc crust together with associated Wagga-Omeo Zone back-arc (and, in Queensland, parts of the adjacent continent – eg. the Anakie Inlier; Offler et al., 2011; and Nebine Ridge; Finlayson & Collins, 1987; see Figure 3) became variously rifted, fragmented, translated and clockwise rotated during Silurian orocline growth, collectively chasing the oceanward-retreating eastern hinge of the Lachlan Orocline, in a persistently extensional/dextral transtensional setting (Collins, 2002b) similar to that envisaged for the adjacent, younger New England Orogen (Rosenbaum, 2012). Due to the transtensional setting that precipitated and accompanied Silurian LFB modification, the Ordovician terrane fragments can preserve little internal evidence of their Silurian lateral translation, other than the presence of thin linear 'rifts' and 'basins' and syn-rift intrusions of this age that surround, bury and/or intrude the fragment margins and so typically obscure bounding relationships. Some fragments do, however, show clear structural evidence of significant internal extension at this time as, for example, Silurian flat-lying high-temperature metamorphic complexes imposed on Ordovician terranes.

By the end of the Silurian, different parts of the previously linear and simple Ordovician continent-fringing intra-oceanic supra-subduction zone system had been modified into a complex intermix of terrane fragments, including some parts rotated to such high strike-angles that they have long been considered entirely different orogenic systems (the Thomson Fold Belt; Spampinato et al., 2015; Doublier et al., 2018). (Figure 1)

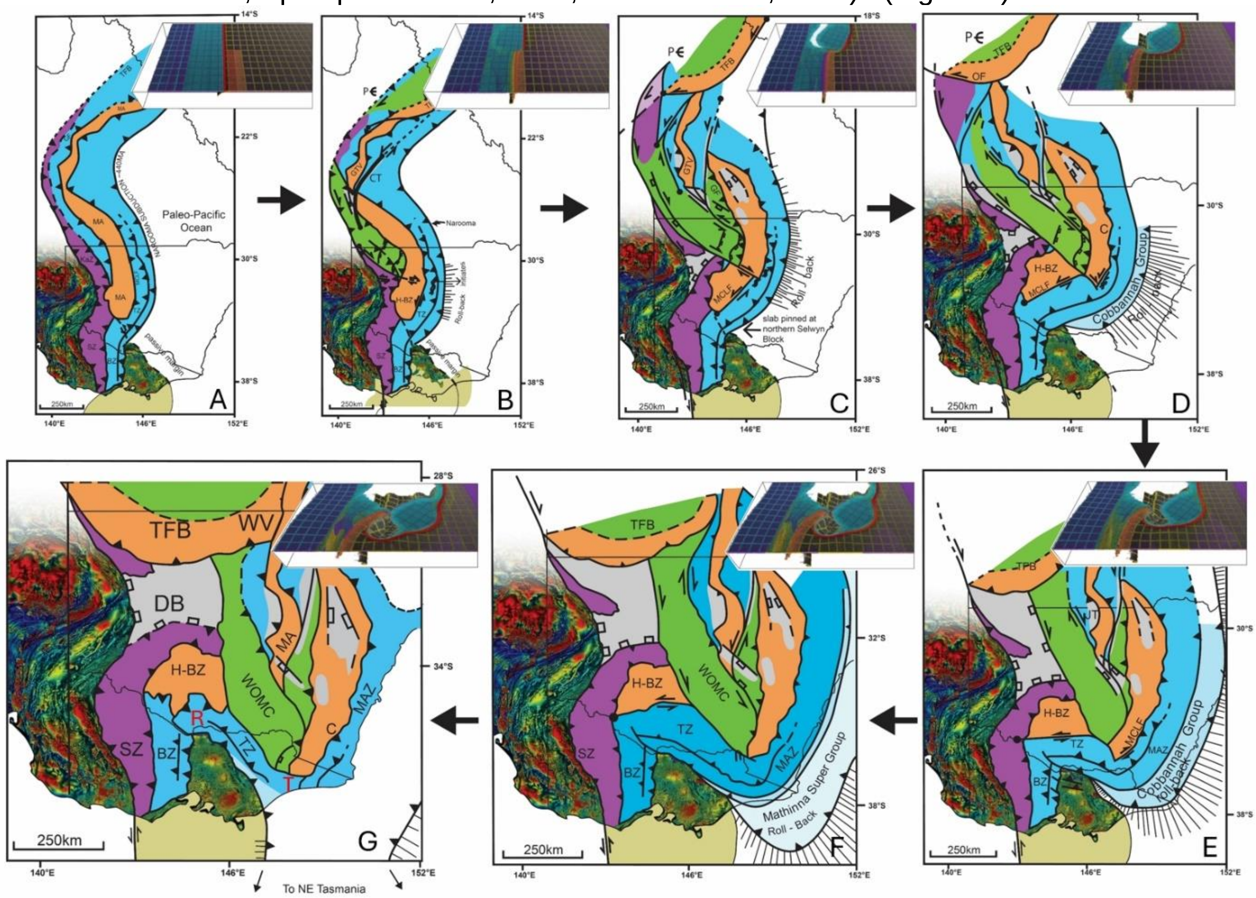

Figure 1: Time-sequence summary of the progressive evolution of the LFB and growth of the Lachlan Orocline on mainland Australia from ~445 Ma (A) - 405 Ma (G), with inset interval snap-shots of the numerical model 80s of Moresi et al. (2014) with an age of oceanic lithosphere (~80My), geographic scale and run-duration directly comparable to the Lachlan Orocline. BZ=Bendigo Zone; DB=Darling Basin; C=Cooma Complex; CB=Cobar Basin; GTV= Goonumbla-Trangie Volcanic Belt; H-BZ=Hay-Booligal Zone; KaZ=Kayrunnera Zone; MA=Macquarie Arc; MAZ-Mallacoota Zone; SZ=Stawell Zone; TFB = Thomson Fold Belt; TZ=Tabberabbera Zone; WOMC=Wagga-Omeo Metamorphic Complex. **R** = Riverina Hinge. **T** = Tambo Hinge

Our review of Victorian, NSW and Qld Cambrian-Ordovician geology in the light of modern convergent margin systematics and diagnostic attributes has identified clear Ordovician arc, back-arc, fore-arc, accretionary and intraplate components, spatially ordered in a way that demands continent-dipping subduction polarity throughout the Ordovician, particularly in NSW. Although atypical ordering exists in places (eg: multiple parallel belts of Macquarie Arc volcanics separated by atypical coeval rocks such as Kirribilli Formation in NSW, and the east-dipping and facing Ordovician accretionary rocks of the Tabberabbera Zone in Victoria), these can be explained by subsequent tectonism (eg. Packham, 1987; Fergusson 2009; see Figure 1) without need to invoke additional complexity into the Ordovician convergent margin system.

Lachlan Orocline growth is attributed to Silurian-aged asymmetric slab ‘rollback’ of the NSW portion of a single, simple, west- (ie continent-) dipping subduction zone that had been active along the NSW- Queensland portion of the East-Gondwana margin throughout the Ordovician. Silurian asymmetric slab ‘rollback’ of the subduction zone portion that lay in NSW in the Ordovician is attributed to the collision of an exotic microcontinent Vandieland (Cayley, 2011) into the southern end of the Macquarie Arc subduction zone (Cayley, 2012; Moresi et al. 2014) beginning at the end of the Ordovician. Vandieland comprises Proterozoic western Tasmanian crust and its northern Selwyn Block extension into central Victoria (Cayley et al., 2002). Vandieland geology shares key Proterozoic geological characteristics with Antarctic Gondwana, was likely a legacy of Rodinia breakup (Moore et al, 2016) and was definitively involved in, and cratonised by, Cambrian Delamerian orogenesis. This is a key feature that sets it apart from the conformable Early Cambrian – Ordovician sea-floor successions that underpin the rest of the Lachlan Orogen, well exposed and long understood in central and eastern Victoria (VandenBerg,1991) and in SE NSW (Stokes et al 2015; Packham et al 2016) and now being identified in central-west NSW (P. Blevin, pers. comm. May 2024).

Following Delamerian orogenesis, Vandieland became separated from Gondwana as part of the Paleopacific plate, which mostly comprised undeformed Cambrian MORB, intra-oceanic arc and back-arc sea-floor crust now exposed in adjacent parts of the LFB in Victoria. Post-Delamerian, the Paleopacific plate appears to have commenced sinistral-oblique subduction beneath the eastern edge of NSW and Qld Gondwana throughout the Ordovician, forming the Macquarie Arc in NSW and Qld in the process. Being embedded in the Paleopacific plate, Vandieland was drawn obliquely out from the east-Gondwana margin and northwards towards the Macquarie Arc trench (Cayley, 2011). Its eventual end-Ordovician collision into the southern end of the Macquarie Arc subduction zone (Figure 1A) was inevitable.

Continental crust is buoyant so that Vandieland resisted subduction after collision, instead locally congesting and stalling the lateral advance of the downgoing Paleopacific oceanic plate within which the microcontinent was embedded. With lateral Paleopacific plate-advance dramatically slowed, continued subsidence of mafic oceanic plate portions north of Vandieland under the influence of gravity caused rapid trench retreat or ‘roll-back’ of the uncongested portions oceanward (Figure 1B). Slab ‘rollback’ collapsed the Ordovician LFB supra-subduction crust in NSW and Qld into persistent regional-scale dextral transtension, chasing the retreating plate boundary. This is a ‘tectonic mode switch’ (Collins, 2002a; Cayley, 2015) and is preceded by, and coincides with, introduction of a host of mineral systems, including a pulse of metalliferous magmatism into the Macquarie Arc. The Cadia, Parkes, Ridgeway, etc porphyry systems were formed by decompression anatexis at this time (Huston, et al., 2015; Figure 2).

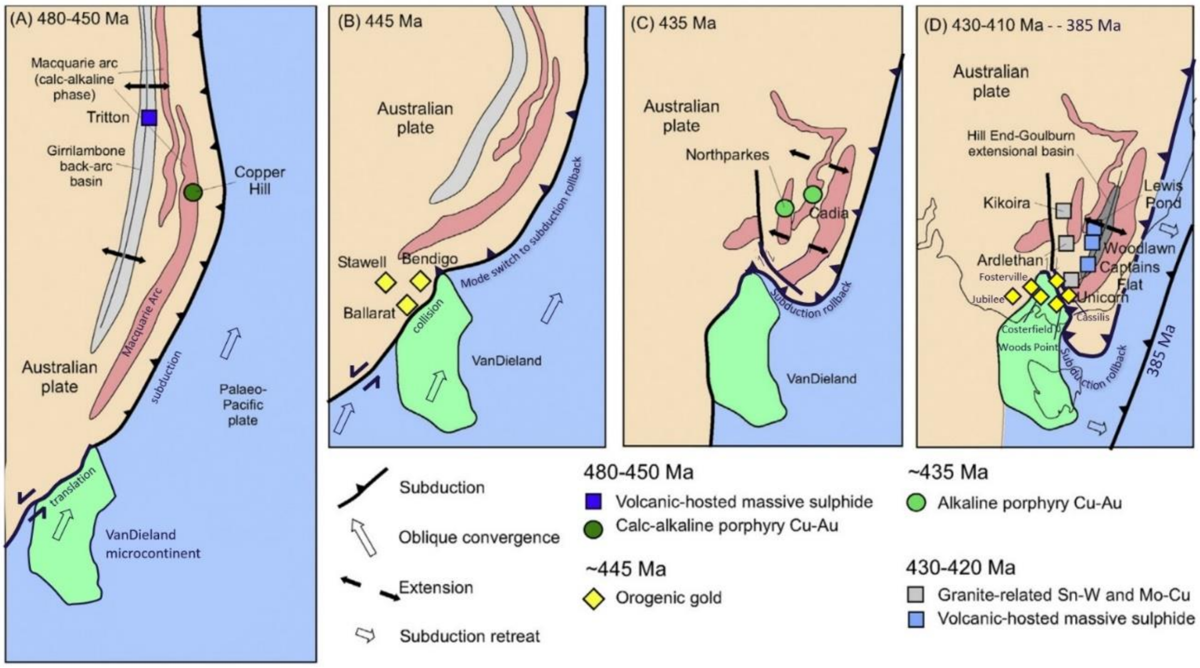

Figure 2: The Lachlan Orocline concept (Cayley, 2012; Cayley & Musgrave, in prep.) envisages the Ordovician proto-Lachlan Fold Belt as a simple linear subduction/accretion system (including the Macquarie Arc) developed along the east Gondwana margin (A). In the Late Ordovician the microcontinent VanDieland, embedded within the Paleopacific lower plate, was drawn into the southern end of the subduction zone, congesting it (B). Oblique collision with amagmatic parts of the Gondwana plate south of the arc across a sinistral transform fault at this time formed the Bendigo Zone (and Bendigo Zone orogenic gold). (C) With Paleopacific slab advance stalled by the buoyant microcontinent, the uncongested parts of the down-going slab fell into asymmetric roll-back, pivoting around the apex of the collider, dismembering, and translating the Macquarie Arc, which was intruded by phases of porphyry mineralisation, and forming a highly curved oroclinal trench (Moresi et al., 2014; Silurian LFB dismemberment described in the text is not unpacked in this summary figure – see Figure 1 for details). (D) As the northern and then eastern parts of Vandieland were drawn progressively into the trench, the collider was enveloped entirely by LFB suprasubduction zone crust, with widespread crustal thickening upon the collider. Eventually the trench reorganised to become linear once more, with final phases of orogenic gold introduced (~385 Ma). Figure adapted from: Huston et al., 2015; Moresi et al., 2014, Cayley & Musgrave, in prep.

With the southern part of the Macquarie Arc subduction zone (and downgoing Paleopacific slab) pinned at the point of Vandieland collision, roll-back of the adjacent uncongested slab was forced into asymmetry, wrapping clockwise around, and therefore being progressively further congested by, the northeastern and then eastern flank of the Vandieland microcontinent (e.g. Cayley, 2012; Moresi et al, 2014; Figure 1C-F).

Plan-view clockwise rotation and progressive congestion of the parts of the formerly linear and uniformly continentally-dipping subduction zone closest to the region of microcontinental collision continued throughout the Silurian, progressively wrapping this part of the subduction zone, together with the accretionary wedge that had developed above it in the Ordovician, around the eastern margin of Vandieland, rotating the formally continental-dip of this subduction system into a local oceanward dip-direction in the process, thus forming the accretionary Tabberabbera Zone (Collins & Vernon, 1992; VandenBerg et al., 2000) in its presently observed orientation as the Lachlan Orocline middle limb.

The Tabberabbera Zone is the key feature that inspired interpretation of the central east-dipping subduction zone in the Gray & Foster (1998) hypothesis. The congested subduction zone segment that underlies the Tabberabbera Zone accretionary wedge is still preserved today as the Governor Fault Zone, a major, kilometres-thick, east-dipping mega-thrust that separates the Selwyn Block footwall to the west from the overthrust Tabberabbera Zone accretionary crust hangingwall to the east, now definitively imaged in the SLaCT deep seismic reflection data (Cayley et al., 2019; 2022; in prep).

Ongoing southeastwards trench retreat at typical modern ~5-8 cm/year plate-tectonic rates for ~30 million years progressively grew the length this rotated portion into the middle, east-dipping limb of a large, vertically plunging Z-shaped oroclinal fold that progressively wrapped the entire eastern margin of Vandieland, eventually extending down into northeastern Tasmania (Figure 1G). This scenario supports, and provides regional context for, interpretations of northeast Tasmania that note similarities – including structural similarities such as recumbent folds – between the Ordovician Tippogoree Group in northeast Tasmania and the coeval Pinnak Sandstone of the Tabberabbera Zone (Reed, 2001). In this style of interpretation the Governor Fault extension south into Tasmania was positioned near the present-day Tyers Fault System (Direen & Leaman, 1997) which is a younger, subsequent structure.

Two broad, rounded, subvertically-plunging orocline hinges separate the Tabberabbera Zone from coeval but west-dipping and north-trending Ordovician-aged thrust-systems that are preserved to the west (Bendigo Zone; Cayley et al., 2011) and east (Kuark/Mallacoota zone / Narooma Terrane; eg Powell, 1983; Miller & Gray 1997) in Victoria and SE NSW.

The Riverina Hinge marks the transition from the northern Tabberabbera Zone westwards into the Bendigo Zone. It marks the point of initial Vandieland collision into the Macquarie Arc subduction zone system ('**R**' in Figure 1G). It is exposed only intermittently due to Murray Basin cover, but modern potential geophysics allows scattered outcrops to be linked together with confidence to define its overall form. Its geometry at crustal scale, including the northerly dip of the Governor Fault Zone that marks the initial point of continental collision, has been imaged in deep seismic data (Cayley et al., 2011).

The Tambo Hinge transition from the southeastern Tabberabbera Zone eastwards into the Kuark and Mallacoota Zones is well exposed in the southern Victorian Alps and has been mapped in great detail ('**T**' in Figure 1G). The core of this hinge subsequently became the locus of transtensional rifting in the Early Devonian to form the Buchan Rift, however inversion of this rift in the Middle Devonian Tabberabberan Orogeny (VandenBerg et al., 2000) evicted much of the Devonian rift fill (Ogden et al., 2016), particularly in the south, so that the gap between Ordovician outcrops that span the along-strike transition between the Tabberabbera and Kuark/Mallacoota zone transition is only a few km wide in places, inconsequential for interpretation of Ordovician-Silurian continuity across the Tambo Hinge.

Oroclinal folds formed by asymmetrically pinned slab rollback are characterised by a growth history that can involve simultaneously increasing amplitude and wavelength (eg. Schellart & Lister, 2004). Which such characteristics, the folds can exhibit exponentially increasing amounts of extension within their cores. The Tambo Hinge exhibits these characteristics and provides a logical and area-balanced scenario that can accommodate the whole of the rest of the Lachlan Fold Belt, including the entirety of the Macquarie Arc and extensions in Australia, becoming progressively fragmented and drawn southeastwards by hundreds of kilometres throughout the Silurian. These rocks were migrating and collapsing laterally into the progressively growing and laterally migrating Tambo Hinge core (Figure 1C-1E).

Combined with eastwards rollback of the rest of the continental-dipping portions of the former Macquarie Arc subduction zone throughout the Silurian (Collins, 2002), also triggered by Vandieland collision (Moresi et al., 2014), the start of the Silurian marks an abrupt tectonic mode-shift to persistent dextral-dominated transtension that affected the entire Australian portion of the east Gondwana convergent margin. Much of this system subsided back below sea-level to receive rejuvenated marine sedimentation throughout the Silurian and Early Devonian (Fergusson, 2010), while also rifting, extending, fragmenting and clockwise-rotating, locally juxtaposing and intermixing fault-slices of arc-crust with fault-slices of accretionary and back-arc crust in disordered ways not observed in modern unmodified subduction-accretion systems (eg. Kirribilli Formation; Packham, 1987).

Southeastwards transtensional collapse of Lachlan Fold Belt suprasubduction zone crust related to Lachlan Orocline growth appears to have followed a classic tectonic progression (eg. Buck, 2012): Early ‘core complex’ modes of extension reflect early fragmentation of the LFB and created the Early Silurian high-T Omeo Metamorphic Complex (Morand, 1990) and the Cooma and Kuark metamorphic complexes. As strain became increasingly partitioned into fractures between the fragments, LFB collapse transitioned into an intermediate ‘wide rift’ mode, involving the opening of large basins, including the large Middle-Silurian Darling Basin and the Hill End and Tumut troughs. As the regional stress-field stabilised into persistent dextral transtension, a more long-lived ‘narrow rift’ mode developed, whereby conjugate transtensional fault networks were able to link up and persistently feed crustal blocks – including Macquarie Arc segments – southwards into the retreating and growing Tambo Hinge core, continuing throughout the mid-late Silurian and into the Early Devonian. Such elongate fault networks are marked by features such as the lithospheric-scale dextral strike-slip Bootheragandra / Kancoona / Kiewa Fault, the Cowra Trough, and related Siluro-Devonian magmatic complexes.

Thus the entire LFB, all the pre-Silurian mineral deposits it contained, and eventually even the North Australian Craton and surrounding regions were drawn southwards into and/or towards the Lachlan Orocline core (Figure 3).

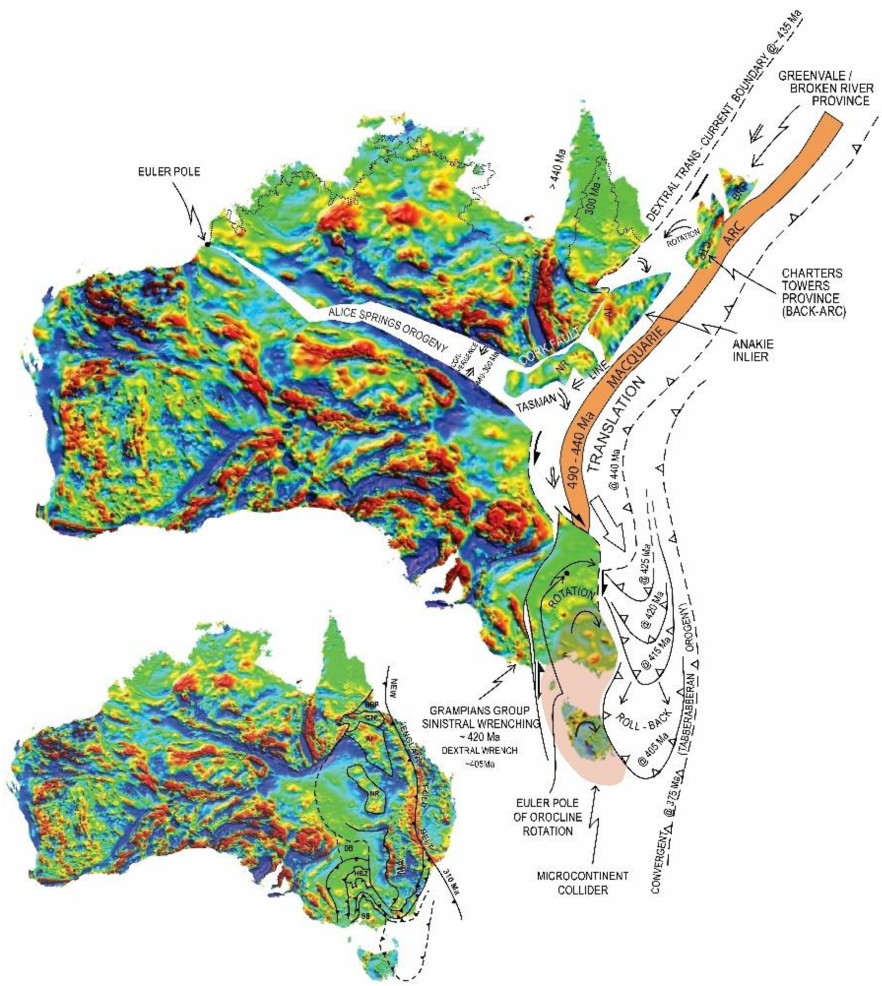

Figure 3: TMI image of Australia (GDA94 transverse Mercator to exaggerate relative scale of southern Australia), depicting Vandieland (orange shading; SB=Selwyn Block), interpreted pre-Silurian positions of the Nebine Ridge (NR), Anakie Inlier (AI), Macquarie Arc (MA; HBZ), Mossman Orogen (CTP=Charters Towers Province; BRP=Broken River Province), and Lachlan Orocline evolution, depicting successive positions of the East-Gondwanaland subduction trench as it evolved and migrated east and south from 440 to 375Ma. Inset: Post- 360 Ma geology (including the New England Orogen).

By the Early Devonian, the entire eastern flank of Vandieland had become drawn against rotated Macquarie Arc accretionary wedge material that now formed the middle limb of the Lachlan Orocline. At this point the subduction zone underlying southeastern Australia and northeastern Tasmania was highly folded, the folded middle-limb component highly congested and stalled by the eastern flank of Vandieland but evidently remaining intact at depth to continue acting as the plate-boundary barrier that had, throughout the Silurian, separated the rampant upper-plate dextral transtension within the Tambo Hinge core from the lower plate that contained Vandieland and the Bendigo Zone and which preserves no evidence of Silurian tectonism.

The common expression of the sinistral-transpressional Middle Devonian Tabberabberan Orogeny in the rock-record across the width of Eastern Australia, across the width of Tasmania, in the Robertson Bay Terrane in North Victoria Land, Antarctica and even in New Zealand indicates that, by the Middle Devonian, the highly folded and congested east-dipping portion of the Gondwana-Paleopacific plate boundary that had partitioned tectonism within the LFB throughout the Silurian was no more. The entire system had reunited in a simple, linear, suprasubduction zone system above a reestablished uniformly continent-dipping subduction zone aligned along the eastern Gondwana margin, but now further outboard. The Tabberabberan Orogeny shows that by the Middle Devonian this simplified slab was undergoing uniform Andean-style trench advance along its length.

The change from a highly curved, partly congested subduction zone in the Silurian to a simple west-dipping subduction zone located farther outboard in the Middle Devonian necessitates detachment of east-dipping, congested portion of the subducted Paleopacific slab from beneath the middle limb of the Lachlan Orocline. Slab detachments involve either ‘tearing’ or the opening of ‘slab windows’ that then grow laterally. Each process is expected to leave a number of characteristic legacies in the directly overlying rock-record.

The search for such characteristic legacies ended up in Bass Strait and in western Tasmania, where a second-order isoclinal orocline – the Early Devonan Dundas-Fossey Orocline – and associated lithospheric-scale rifting and magmatism, were identified from the distribution of Cambrian calc-alkaline rocks and associated sequences, including in legacy drillholes (Cayley & Musgrave, in prep.). Initiation of this second-order orocline is interpreted to involve lithospheric tearing in response to the opening of a ‘slab window’ beneath the Bass Strait portion of the central Lachlan Orocline limb. This slab window grew laterally north and south away from the point of initiation beneath the middle Lachlan Orocline limb to facilitate total separation of the congested east-dipping slab component from its Vandieland margin.

Slab windows cause initially tightly focussed and therefore rapid asthenospheric flows, and it is the focussed southeastwards flow of asthenosphere beneath Bass Strait that is considered to be the geodynamic driver of long term rift-related lithospheric thinning that is expressed directly above, and to this day, as the Bass Strait topographic depression. Localised asthenospheric flow rafted the overlying lithosphere, producing lithospheric tearing and localised clockwise rotation of lithosphere that eventually formed the promontory-like eastern limb of the Dundas-Fossey Orocline. The Dundas-Fossey Orocline eastern limb was apparently tightened to isoclinal in the Middle Devonian at the culmination of the compressional Tabberabberan Orogeny, with the Tiers Fault System formed from inversion of extensional faults along the flank of the lithospheric promontory.

Modern geological and geophysical tools are able to constrain and test (ie falsify) such hypotheses. Paleomagnetic studies can test for evidence of rotations of the appropriate magnitude and at the appropriate times (Musgrave, 2015; Musgrave & Job, 2020). Seismic reflection and passive seismic data image geometries at depth, and at lithospheric scale, constrain and test geometric predictions of Lachlan Orocline concept (Drummond et al., 2000; Rawling et al., 2011; Cayley, 2016; Rawlinson et al., 2011, 2014; Pilia et al, 2015; Cayley et al., 2019, in prep.). Magnetotellurics can identify crustal scale conductivity trends (Kirkby et al., 2020). Geochronology and geochemistry and good old targeted field mapping and reinterpretation of legacy datasets constrains and tests other critical predictions of the model (Cayley & Musgrave, in prep).

Understanding and constraining the origins and geodynamics and nature of the resolution of this process has enabled constrained, area-balanced plan-view fold-belt-scale retro-deformations to be constructed, based on regional potential field (mainly aeromagnetic) datasets. Such reconstructions reveal a possible pre-orocline configuration for the LFB, together with the original context and inter-relationships of contained pre-orocline mineral systems (Figure 1). We have undertaken higher resolution retrodeformations of key parts of this event where data allows (eg. Cayley et al, 2018). This style of constrained reconstruction has potential to unlock vast areas of concealed Eastern Australian geology to effective predictive exploration for repeats of mineral systems in terranes already understood and known to be economic elsewhere. This is the ultimate aim of the UNCOVER initiative.

In a region of relatively poor exposure (Australia has low topographic relief, and much of the LFB lies buried beneath post-Early Palaeozoic cover rocks), a robust geodynamic understanding of the evolution of the LFB is critical in order to improve understanding of the possible causes for, and context of, its known contained world class mineral endowment (Huston et al., 2015), including the current quest to understand Australia's Critical and Strategic minerals endowments. An additional opportunity exists for other endowment types so-far unknown in eastern Australia, by comparison with modern systems of similar configuration.

REFERENCES

BUCK, R.W., 2012. Modes of continental lithospheric extension. Journal of Geophysical Research: Solid Earth 96, 20161 - 20178

CAYLEY, R.A., 2010. South-directed oroclinal folding in the Lachlan Fold Belt: unravelling mid-late Silurian fold belt assembly to solve apparent Ordovician–early Silurian complexity. Geological Society of Australia, 2010 Australian Earth Sciences Convention (AESC) 2010, Earth systems: change, sustainability, vulnerability. Abstract No 98 of the 20th Australian Geological Convention, National Convention Centre, Canberra, Australian Capital Territory. July 4-8 July, 59-60.

CAYLEY, R.A., 2011. Exotic crustal block accretion to the eastern Gondwanaland margin in the Late Cambrian – Tasmania, the Selwyn Block, and implications for the Cambrian-Silurian evolution of the Ross, Delamerian and Lachlan Orogens. Gondwana Research 19, 628 – 649.

CAYLEY, R. 2012. Oroclinal folding in the Lachlan Fold Belt: Consequence of SE-directed Siluro-Devonian subduction rollback superimposed on an accreted arc assemblage in eastern Australia. In: Selwyn Symposium 2012. Geol. Soc. Aust. Abst, 103*,* 34-43.

CAYLEY, R.A., 2015. The giant Lachlan Orocline - a powerful new predictive tool for mineral exploration under cover across *eastern Australia.* Australian Institute of Geoscientists Bulletin*, 62, 29-38.*

Cayley, R.A., 2016. Revised project proposal: the Eastern Victorian / Central-East Lachlan Deep Seismic Reflection Transect. Geological Survey of Victoria Unpublished Report 2016/1. Earth resources Policy and Programs, 19 pp.

CAYLEY R. A., KORSCH R. J., MOORE D. H., COSTELLOE R. D., NAKAMURA A., WILLMAN C. E., RAWLING T. J., MORAND V. J., SKLADZIEN P. B. & O'SHEA P. J., 2011. Crustal architecture of central Victoria. results from the 2006 deep crustal reflection seismic survey. Australian Journal of Earth Sciences 58, 123–156.

CAYLEY, R.A., MCLEAN M.A., SKLADZIEN, P.B., & CAIRNS, C.P., 2018. Stavely Project - Regional 3D Geological Model. Stavely Project Report 3. Geological Survey of Victoria. Department of Economic Development, Jobs, Transport and Resources.

CAYLEY, R.A. & MUSGRAVE, R.J., in prep. The giant Lachlan Orocline – a new geodynamic model for the Ordovician-Devonian evolution of Eastern Australia. Currently being re-scoped for submission to Australian Journal of Earth Science.

CAYLEY R. A., SKLADZIEN P.B., CAIRNS C.P., HAYDON S., MCLEAN M.A., TAYLOR D.H., FOMIN T., COSTELLOE R.D., KIRKBY A., JINGMING D., DOUBLIER M., MUSGRAVE R., STOLZ N., SPAMPINATO G., GILMORE P., GREENFIELD J. & RAWLING T.J., 2019. The Southeast Lachlan Crustal Transect – planning, acquisition and some preliminary results from a 629 km long deep seismic reflection profile across the Australian Alps, Mineral Exploration in the Tasmanides 2019, AIG Bulletin 69, Australian Institute of Geoscientists.

CAYLEY, R.A., SKLADZIEN, P.B., CAIRNS, C.P., HAYDON, S., MCLEAN, M.A., TAYLOR, D.H., FOMIN, T., COSTELLOE, R.D., KIRKBY, A., JINGMING, D., DOUBLIER, M.P., MUSGRAVE, R.J., STOLZ, N., SPAMPINATO, G., GILMORE, P., GREENFIELD, J., CARLTON, A.A., & RAWLING, T.J. 2022. Profiles across a fossil congested subduction zone – is the Governor Fault in Victoria a ~5 km thick megathrust progressively superimposed on a probable Rodinian-age passive margin, and a control on the distribution of subsequent mantle-derived dykes and orogenic gold mineralisation? In: ARMISTEAD, S. E. (ed.). Specialist Group in Tectonics and Structural Geology conference. Geological Society of Australia Abstracts Number AB 134, pp. 11.

CAYLEY, R.A., SKLADZIEN, P.B., CAIRNS, C.P., HAYDON, S.J., MCLEAN, M.A., TAYLOR, D.H., FOMIN, T., COSTELLOE, R.D., KIRKBY, A.L., DUAN, J., DOUBLIER, M.P., MUSGRAVE, R.J., STOLZ, E.M., SPAMPINATO G., GILMORE, P.G., CARLTON, A.A., GREENFIELD, J.E., RAWLING, T.J., in prep, Geological interpretation of deep 2D seismic reflection survey lines 18GA-SL1, 18GA-SL2 and 18GA-SL3 undertaken as part of the Southeast Lachlan Crustal Transect. Geological Survey of Victoria. Department of Jobs, Precincts and Regions.

CAYLEY, R. A., TAYLOR, D. H., VANDENBERG, A. H. M & MOORE, D. H., 2002. Proterozoic–Early Palaeozoic rocks and the Tyennan Orogeny in central Victoria: the Selwyn Block and its tectonic implications. Australian Journal of Earth Science 49, 225–254.

COLLINS, W.J., 2002a. Hot Orogens, tectonic switching and creation of continental crust. Geology 30, 535-538

COLLINS W.J. 2002b. Nature of extensional accretionary orogens. *Tectonics* 21 (4);1258-1272 (10.1029/2000TC001272).

COLLINS, W.J. & VERNON, R.H., 1992. Palaeozoic arc growth, deformation and migration across the Lachlan Fold Belt, southeastern Australia. Tectonophysics, 214, 381-400.

CRAWFORD, A.J., 1988. Cambrian. In: DOUGLAS, J.G. & FERGUSSON, J.A. (eds.) Geology of Victoria, edition 2, Victorian Division of the Gological Society of Australia, Melbourne, 37-62.

CRAWFORD, A.J., MEFFRE, S., SQUIRE, R.J., BARRON, L.M. & FALLOON, T., 2007. Middle and Late Ordovician magmatic evolution of the Macquarie Arc, Lachlan Orogen, New South Wales. Australian Journal of Earth Sciences 54, 181-214.

DIREEN, N. G. & LEAMAN, D. E. 1997. Geophysical modelling of structure and tectonostratigraphic history of the Longford Basin, Northern Tasmania. Exploration Geophysics 28, 29–33.

DOUBLIER, M. P., PURDY, D. J., HEGARTY, R., NICOLL, M. G., & ZWINGMANN, H. (2018). Structural elements of the southern Thomson Orogen (Australian Tasmanides): a tale of megafolds. Australian Journal of Earth Sciences, 65(7–8), 943–966. https://doi.org/10.1080/08120099.2018.1526213

FERGUSSON, C.L., 2009. Tectonic evolution of the Ordovician Macquarie Arc, central New South Wales: arguments for subduction polarity and anticlockwise rotation. Australian Journal of Earth Sciences 56, 179–194.

FERGUSSON, C. L., 2010. Plate-driven extension and convergence along the East Gondwana active margin: Late Silurian-Middle Devonian tectonics of the Lachlan Fold Belt, southeastern Australia. Australian Journal of Earth Sciences 57, 627 – 649.

FERGUSSON, C. L., GRAY, D. R. & CAS, R. A. F., 1986. Overthrust terranes in the Lachlan Fold Belt, southeastern Australia. Geology 14, 519–522.

FINLAYSON, D. M., & COLLINS, C. D. N. (1987). Crustal differences between the Nebine Ridge and the central Eromanga Basin from seismic data. Australian Journal of Earth Sciences, 34(2), 251–259. https://doi.org/10.1080/08120098708729408

GLEN, R.A., CRAWFORD, A.J., PERCIVAL, I.G & BARRON, L.M., 2007. Early Ordovician development of the Macquarie Arc, Lachlan Orogen of southeastern Australia. Australian Journal of Earth Sciences 54, 167 – 179.

GRAY D.R. & FOSTER D.A. 1998. Character and kinematics of faults within the turbidite-dominated Lachlan Orogen: implications for tectonic evolution of eastern Australia. Journal of Structural Geology 12, 1691–1720.

HUSTON, D.L., MERNAGH, T.P., HAGEMANN, S.G., DOUBLIER, M.P., FIORENTINI, C., CHAMPION, D.S., LYNTON, J.A., CZARNOTA, K., CAYLEY, R.A., SKIRROW, R., & BASTRAKOV, E., 2015. Tectono-metallogenic systems – the place of mineral systems within tectonic evolution, with an emphasis on Australian examples. Ore Geology Reviews 76, 168-210 doi:10.1016/j.oregeorev.2105.09.005

KIRKBY, A.L., MUSGRAVE, R.J., CZARNOTA, K., DOUBLIER, M.P., DUAN, J., CAYLEY, R.A. & KYI, D., 2020. Lithospheric architecture of a Phanerozoic orogen from magnetotellurics: AusLAMP in the Tasmanides, southeast Australia, Tectonophysics 793, https://doi.org/10.1016/j.tecto.2020.228560.

MORESI, L., BETTS, P.G., MILLER, M.S. & CAYLEY, R.A., 2014. Dynamics of continental accretion. Nature 508, 245-248. doi:10.1038/nature13033

MILLER, J. MC. L. & GRAY, D.R., 1997. Subduction related deformation and the Narooma anticlinorium, eastern Lachlan Fold Belt. Australian Journal of Earth Sciences 44, 237-251.

MOORE, D.H., BETTS, P.G., & HALL, M., 2016. Constraining the VanDieland microcontinent at the edge of East Gondwana, Australia, Tectonophysics, 687, pp 158-179. https://doi.org/10.1016/j.tecto.2016.09.009.

MORAND, V.J., 1990. Low-pressure regional metamorphism in the Omeo Metamorphic Complex, Victoria. Australia. Journal of Metamorphic Geology 8, 1 – 12.

MUSGRAVE, R.J., 2015. Oroclines in the Tasmanides. Journal of Structural Geology 80, 72-98.

MUSGRAVE, R. J. & JOB, K., 2020. Palaeomagnetism of the Dundas–Fossey Trough, Tasmania: Oroclinal rotation and Late Cretaceous overprinting. Tectonophysics 786. https://doi.org/10.1016/j.tecto.2020.228453.

OGDEN, T., MCLEAN, M., RAWLING, T. & CAYLEY, R., 2016. Redefined crustal structure of the Buchan Rift, northeast Victoria: evidence from potential field modelling of newly acquired land-based gravity data. Australian Journal of Earth Sciences, 63(5), pp. 551-570. doi:10.1080/08120099.2016.1229692

OFFLER, R., PHILLIPS, G., FERGUSSON, C. & GREEN, T., 2011. Tectonic Implications of Early Paleozoic Metamorphism in the Anakie Inlier, Central Queensland, Australia. Journal of Geology. 119. 10.1086/661191.

PACKHAM, G.H., 1987. The eastern Lachlan fold belt of southeast Australia. A possible Late Ordovician to Early Devonian sinistral strike slip regime. IN: LEITCH E.C. & SCHEIBNER, E. eds. Terrane Accretion & Orogenic BGelts,, 67 – 82, AGU Geodynamic Series 19.

PACKHAM, G. H., & HUBBLE, T. C. T. (2016). The Narooma Terrane offshore: a new model for the southeastern Lachlan Orogen using data from rocks dredged from the New South Wales continental slope. Australian Journal of Earth Sciences, 63(1), 23–61. https://doi.org/10.1080/08120099.2016.1150346

PILIA, S., RAWLINSON, N., CAYLEY, R.A., BODIN, T., MUSGRAVE, R., READING, A.M., DIREEN, N.G. & YOUNG, M.K., 2015. Evidence of micro-continent entrainment during crustal accretion. Scientific Reports 5. Doi: 10.1038/srep08218

POWELL, C. McA., 1983. Tectonic relationship between the Late Ordovician and Late Silurian palaeogeographies of southeastern Australia. Journal of the Geological Society of Australia 30, 353 – 373.

RAWLING, T.J., OSBORNE, C.R., MCLEAN, M.A., SKLADZIEN, P.B., CAYLEY, R.A. & WILLIAMS, B., 2011. 3D Victoria Final Report. GeoScience Victoria 3D Victoria Report 14. Department of Primary Industries.

RAWLINSON, N., ARROUCAU, P., MUSGRAVE, R. CAYLEY, R., YOUNG, M & SALMON, M., 2014. Complex continental growth along the proto-Pacific margin of East Gondwana. Geology 42, 783-786.

RAWLINSON, N., KENNETT, B.L.N., VANACORE, E., GLEN, R.A., & FISHWICH, S., 2011. The structure of the upper mantle beneath the Delamerian and Lachlan orogens from simultaneous inversion of multiple teleseismic datasets. Gondwana Research 21, 302-304.

REED, A. R., 2001. Pre-Tabberabberan deformation in eastern Tasmania: a southern extension of the Benambran Orogeny. Australian Journal of Earth Sciences 48, 785 – 796

ROSENBAUM, G., 2012. Oroclines of the southern New England Orogen, eastern Australia, *Episodes*, **35**(1), 187–194.

SCHELLART, W., & LISTER, G. S., 2004. Tectonic models for the formation of arc-shaped convergent zones and backarc basins. *Geological Society of America Special Publication*, *383*, 237 - 258.

SPAMPINATO, G.P.T., BETTS, P. G., AILLERES, L. & ARMIT, R. J., 2015. Early tectonic evolution of the Thomson Orogen in Queensland inferred from constrained magnetic and gravity data. Tectonophysics, 651–652, pp 99-120 https://doi.org/10.1016/j.tecto.2015.03.016.

SQUIRE, R., WILSON, C., DUGDALE, L., JUPP, B. & KAUFMAN, A., 2006. Cambrian backarc-basin basalt in western Victoria related to evolution of a continent-dipping subduction zone. Australian Journal of Earth Sciences. 53. 707-719. 10.1080/08120090600827405.

STOKES, N., FERGUSSON, C.L., & OFFLER, R., 2015. Backarc basin and ocean island basalts in the Narooma Accretionary Complex, Australia: setting, geochemistry and tectonics. Australian Journal of Earth Sciences, 62, 37 - 53.

VANDENBERG, A.H.M., 1991. Kilmore 1:50 000 map geological report. Geological Survey of Victoria Report 91.

VANDENBERG, A. H. M., WILLMAN, C. E., MAHER, S., SIMONS, B. A., CAYLEY, R. A., TAYLOR, D. H., MORAND, V. J., MOORE, D. H. & RADOJKOVIC, A., 2000. The Tasman Fold Belt System in Victoria. Geological Survey of Victoria Special Publication.