Oroclines in the Tasmanides: a revolution in thinking

Robert Musgrave
Tasmanides

Glen, 2005

Geoscience Australia
The 2D Tasmanides?

- Outcrop geology in the Tasmanides dominated by (roughly) N-S strike
- Leads to “2D thinking”
  - E-W cross-sections
- “3D” is just 2D extended along strike

Aitchison & Buckman, 2012

Glen & Meffre, 2009
2D analogues

- **Cordillera**
  - Linear unidirectional accretion, collisions

- **South-west Pacific**
  - Extension and contraction, repeated along same subduction system

- **North-west Pacific**
  - Arc reversal, collision

- But none of these are entirely satisfactory

Aitchison & Buckman, 2012

Collins & Richards, 2008
3D - Curvature?

- Non-linear structure
  - Adelaide Fold Belt
  - New England Orogen
- Only in NEO was this considered significant for tectonic history...
- Mindset breakthrough: tilt-filtered magnetics, allowing clear trace of Stawell Zone curvature under 5 km thick cover
  - Built on initial interpretation of extension of Stawell Zone into NSW by Hallett et al. (2005)
Curvature: tilt filter
Curvature – Rayleigh waves, mid to lower crust

Rawlinson et al, 2014

Pilia et al, 201
Geological conundrum: Repetition of Lachlan Terranes

![Map of Lachlan Terranes](image-url)
Curvature + conundrum = “Cayley hypothesis”

Present

415-410 Ma

440 Ma

430 Ma

405-400 Ma

- Stawell and Kayrunnra zones: Cambrian forearc.
- Wagga-Omeo zone: Ordovician back-arc, metamorphic complex during orocline development.
- Macquarie Arc.
- Bendigo-Tabberabbera-Malacoota zone.
- Thomson Orogen.
- Darling Basin.
- Selwyn Block.
Rollback of a congested subduction zone

Moresi et al, 2014
Testing the Tasmanide oroclines

- Oroclinal models for the Tasmanides resolve some difficult geological problems
- And the numerical modelling of rollback looks very intriguing...
- But are we in danger of arm waving?
- Need to test the orocline hypothesis.
Necessary conditions for an orocline

1. Map-scale curvature of geological structure ("structural arc")

2. Curvature develops during orogeny ("progressive arc") through differential rotation of limbs

Thin-skinned non-rotational arcs – Marshak 2004
Orocline test

- Test rotation by plotting variation in pre-orogenic or early orogenic vector fabric vs variation in strike.
- “Ideal” orocline – plot is linear, gradient = 1
- “Classic” vector is palaeomagnetic declination (Schwartz & Van der Voo, 1983).
- Palaeocurrents

Van der Voo, 2004

Thin-skinned non-rotational arcs – Marshak 2004
Cambrian: Delamerian Orocline

Nackara Arc non-rotational: Marshak & Flöttmann, 1966

Marshak, 2004
Palaeomagnetism: Nackara Arc

Schmidt & Williams, 2010

Adelaide Geosyncline
- Rawnsley Quartzite
- Bonney Sandstone
- Wonoka Formation
- Bunyeroo Formation
- ABC Range Quartzite

Ediacaran
- Brachina Formation
- Nuccaleena Formation
- Elatina Formation
- Trezona Formation

Eonormal
- Ennorama Shale
- Etina Formation
- Sunderland Formation
- Brighton Limestone

Cryogenian
- Tapley Hill Formation
- Tindalina Shale Member
- Willypa Formation
- HI
- Pualco Tillite
- Merijina Tillite

STUURN

138°E 139°E
31°S 32°S 33°S
560 My 590 My 540 My 480 My 640 My 609 My

↑ Elatina ↑ Nuccaleena ↑ Brachina ↑ Bunyeroo ↑ Wonoka

Tuesday 16 June 2015

Geological Survey of New South Wales

New South Wales Resources & Energy
Orocline test – Nackara Arc

$y = 0.9725x + 3.0006$

$R^2 = 0.8101$
Lachlan Orocline test I – Ordovician-Silurian palaeocurrents

\[ y = 0.5748x + 4.5115 \]

\[ R^2 = 0.704 \]

Mean palaeocurrent bearing vs. Zone strike
Palaeomag and the Lachlan orocline
Lachlan Orocline test II – Cambrian palaeomag from Victoria

Mike Tetley, B.Sc. (Hons) student, University of Sydney
New England oroclines

- How many oroclines? 2? 3? 4?
- How much lateral displacement? Which direction(s)?
- Palaeomag interpreted in terms of classical palaeopole approach.

Rosenbaum et al., 2012

Glen & Roberts, 2012

Cawood et al., 2012
NEO: palaeomag orocline test

Palaeomag data from compilation in Cawood et al., 2011. Declination anomaly calculated as difference from declination to corresponding Gondwana pole.

\[ y = 1.1642x - 73.592 \]

\[ R^2 = 0.978 \]
Implications

• Large lateral displacement, rotation, apparent reversal of vergence
  – Removes need for multiple contemporaneous subduction zones.
• Accretion mechanism
• Nature and origin of middle crust below Tasmanides
  – Oceanic vs continental
• Relationship between orogens
  – Lachlan and Thomson
• Modern tectonic (and mineralisation) analogues

Heat and Extension – e.g., Cobar Basin, Goulburn Trough

Compression, fluid expulsion, orogenic gold
Nature of lower crust?

- 20 km low-pass filter emphasises central magnetic high.

60-km upward continuation courtesy Mike Tetley
• Except for SE NSW, topography is a poor fit to Moho depth
  – Not just simple Airy isostasy
  – Suggests tectonic control on crustal thickness

• Deep Moho in east Lachlan correlates with long-$\lambda$ magnetic lows

• Ditto for Curnamona and Adelaide Fold Belt

Moho depth from AusMoho model, Kennett et al., 2011,
Comparison with Glen et al., 2013
Better analogies for the Tasmanides?

• Subduction retreat, congested subduction, tight oroclines, transcurrent faults, all on a continental margin...
• Banda Arc?
  – Wetar VHMS

Spakman & Hall, 2010
Conclusions

• Is the Cayley / Moresi et al model for the Lachlan correct?
  – Probably not in every detail
  – But concept of complexly rotated margin driven by rollback of a congested subduction zone is a valuable new paradigm
  – Oroclinal rotation appears to typify Tasmanides

• Testing by GSNSW
  – More palaeomag in the Lachlan
  – Provenance studies in southern Thomson
  – Kinematics in east Riverina