Palaeomagnetic test of oroclinal rotation in the Dundas Trough, Tasmania

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SUMMARY

Cambrian to Silurian rocks of the Dundas Trough, Tasmania, including the economically important Mount Read Volcanics, follow a curving trend around the northern margin of the Tyennan Block. This arcuate trend has recently been interpreted to be part of an orocline, the eastern limb of which is obscured below Jurassic dolerite. Other workers consider the arcuate trend of the Dundas Trough to be the result of Cambrian rifting, with the underlying basement continuing north below Bass Strait. We tested the orocline hypothesis by palaeomagnetic sampling of rocks from the Owen, Gordon and Eldon groups. Previous palaeomagnetic studies concluded that these rocks were overprinted. By use of modern demagnetisation protocols and principal component analysis of demagnetisation vectors we were able to isolate a pre-deformation characteristic remanence carried by magnetite and hematite from a normal polarity overprint carried only by hematite. The overprint resembles Cretaceous overprints recognised from the eastern Australian seaboard, and thought to be related to Tasman Sea rifting. The characteristic remanence passes the statistical orocline test, confirming the orocline hypothesis for the Dundas Trough. Rocks equivalent to the Mount Read Volcanics therefore continue under Jurassic dolerite cover below eastern Tasmania.

Key words: Palaeomagnetism, Dundas Trough, orocline, Tasmania, overprint

INTRODUCTION

Potential field data (Cayley et al., 2002; McLean et al., 2010; Cayley, 2011) suggest that the Palaeozoic rocks of western Tasmania (the Rocky Cape Block, west of the Arthur Lineament) continue below Bass Strait to Victoria, where they form part of a buried basement terrane below the Melbourne Zone termed the Selwyn Block. Cambrian to early Palaeozoic rocks of the Dundas Trough, including the Mount Read Volcanics and Owen Group, lie east of the Arthur Lineament (Figure 1). Two contrasting interpretations of the northward continuation of the Dundas Trough have been recently proposed. Moore et al. (2013, 2015) redefined the northern extension of the Dundas Trough as their Burnie Zone, and inferred from the potential field data that this zone continues north into Bass Strait, flanking the Rocky Cape Zone. In doing so, they discounted the apparent curvature of the Dundas Trough around the Tyennan Block, visible as a gravity low, as the result of Cambrian rifting, and considered that the underlying basement trends northwards. Cayley (2015) accepted the apparent curvature of the Dundas Trough as a basement-penetrating feature, and proposed that the trough continues under Jurassic dolerite cover in eastern Tasmania to define an isoclinal vertical axis fold, an orocline he ascribed to the same southward roll-back of the Silurian subduction system that has been proposed as the agent driving a larger double hinged orocline in the Lachlan Orogen of NSW and Victoria (Cayley et al., 2012; Moresi et al., 2014).

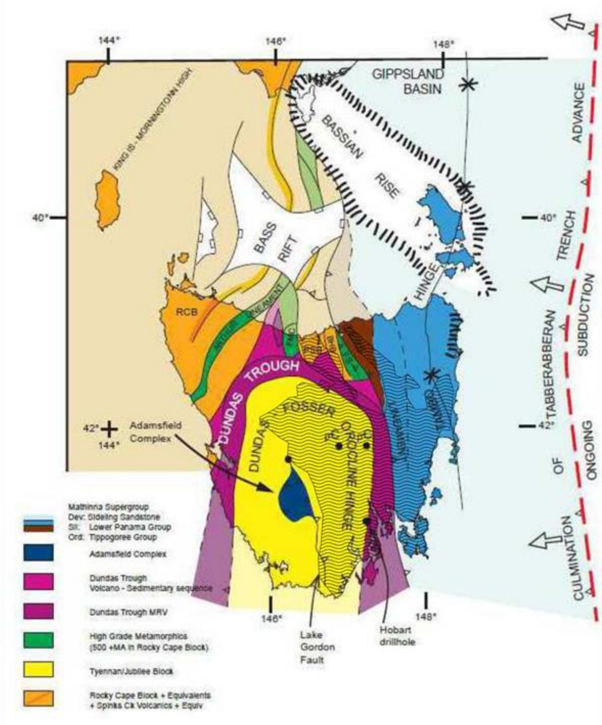

Figure 1: Conceptual model of Dundas Trough orocline, after Cayley (2015), showing major divisions of Palaeozoic Tasmanian geology. The area covered by wavy hatching is obscured by overlying Jurassic dolerite.

Oroclinal rotation can be tested in a statistically rigorous fashion through the palaeomagnetic orocline test (Van der Voo, 2004), which compares changes in declination with changes in strike. Orocline tests applied to existing (but contested) data confirm oroclines in the Nackara Arc of the Flinders Ranges and in the New England Orogen (Musgrave, 2015). Previous palaeomagnetic studies of rocks in the Dundas Trough (Briden, 1967; Delisle et al., 1993) presented results in the more conventional palaeomagnetic pole approach; both identified pervasive magnetic overprinting. Neither previous study made use of more advanced demagnetisation and interpretation protocols, including low-temperature demagnetisation (Dunlop, 2003) and principal component analysis (Kirschvink, 1980). We decided to test the hypothesis of a Dundas Trough orocline by sampling Cambrian through Silurian sedimentary rocks of the Owen, Gordon and Eldon groups, and analysing the samples by a contemporary palaeomagnetic methodology.

METHOD AND RESULTS

Oriented samples were collected as 2.5 cm diameter palaeomagnetic cores with a hand-held drill. In cases of highly siliceous material, oriented blocks of rock were collected for later coring with a drill press in the laboratory. After cutting into 2.2 cm long cylinders, specimens were measured after a series of stepwise increasing thermal demagnetisation steps to a maximum temperature of 550°-610°C. An intermediate step, following the 100°C stage, used liquid nitrogen cooling of the samples and rewarming to room temperature in low-field space within nested mu-metal cylinders. A set of duplicate specimens was demagnetised by the alternating field method to a maximum field of 100 mT. Remanence after each demagnetisation step was measured on a Molspin spinner magnetometer (stronger specimens) and/or a 2G cryogenic magnetometer (weaker specimens). Results were analysed using the Remasoft software package, using principal component analysis (PCA) to define and fit linear demagnetisation segments.

Demagnetisation paths reveal the presence of two major magnetisation components (Figure 2). As noted by previous workers, most specimens display a consistently normal polarity component that often persists to the highest demagnetisation stage. The uniform polarity of this component, and its failure of the fold test (McFadden, 1990), confirm that it is an overprint, and its persistence beyond the magnetite Curie temperature indicates that the carrier is hematite. The direction and polarity of the overprint matches that recognised by Delisle et al (1993), and the corresponding palaeomagnetic pole falls on the mid-Cretaceous (~90-100 Ma) segment of the Australian apparent polar wander path. Magnetic overprints yielding similar poles have been repeatedly recognised in rocks from the eastern seaboard of mainland Australia (Schmidt and Embleton, 1981; Schmidt, 1982; Schmidt et al., 1995; Belica et al, 2017), and have been attributed to thermochemical effects of Tasman Sea rifting. However, many specimens display an additional component, demagnetised over temperatures below 570°C, consistent with a magnetite carrier. Other specimens show evidence that this component is carried by both magnetite and hematite. After isolation by PCA, this component includes antipodal normal and reversed directions, and passes the fold test, indicating that it is a pre-deformational characteristic remanent magnetisation (ChRM).

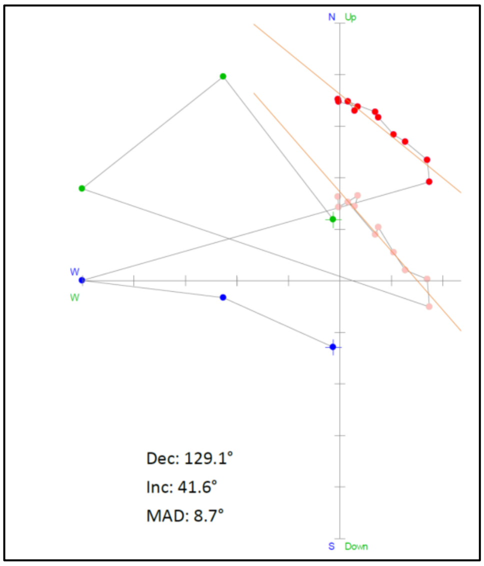

Figure 2: Demagnetisation vector plot illustrating a reversed polarity ChRM carried by magnetite, with a more stable normal polarity overprint carried by hematite. Circular symbols show horizontal (blue and red) and vertical (green and buff) components of demagnetised remanence. Red, buff symbols are selected points for PCA of ChRM; orange lines show best linear fit. The ChRM is reversed polarity. A substantial proportion of NRM remains at the maximum demagnetisation temperature of 610°C, and the negative inclination and roughly northward declination remaining indicate normal polarity.

Declination of the ChRM follows structural strike around the Dundas Trough, and passes the orocline test at >95% confidence (Figure 3). Declinations around the hinge zone appear inconsistent, but two of the three sites in this zone are from units in the Late Ordovician Gordon Group and the Silurian Eldon Group: sites yielding ChRM directions from the two limbs of the trough are from the Cambrian to earliest Ordovician Owen Group. This difference in age should be reflected in an anticlockwise deflection of the ChRM at the younger sites relative to the Own Group sites, due to apparent polar wander of Gondwana over this time (McElhinny et al., 2003). Correcting for this effect restores the younger directions to a close fit to the overall declination–strike best-fit line, making the orocline test for the Dundas Trough even more definitive

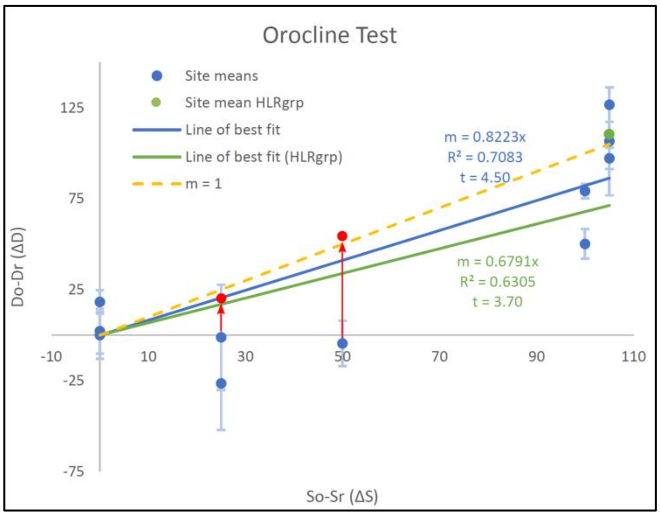

Figure 3: Orocline test for Dundas Trough. Mean site direction data are plotted as ΔD = site declination (D_o) – declination of reference site (D_r), against ΔS = bedding strike at site (S_o) – bedding strike at reference site (S_r). Green symbol combines three sites having same strike at one locality (Highland lakes Road), and green line represents corresponding best fit. Fit to ideal orocline test (gradient = 1) is significantly improved when rotations of younger declinations due to apparent polar wander of Gondwana are included (red symbols).

CONCLUSIONS

Normal overprints, probably acquired during the Cretaceous, obscure the ChRM in Dundas Trough rocks, but PCA of stepwise demagnetisation reveals a ChRM carried in magnetite and hematite which is pre-deformational (and by inference, probably a depositional remanence). Directions from this ChRM pass the orocline test, confirming the hypothesis that the Dundas Trough is an orocline, folded at some time after the early Silurian. This supports a corollary of Cayley's Lachlan orocline model. Rocks of the Dundas Trough, including the mineralised Mount Read Volcanics, are likely to continue under Jurassic Dolerite cover in eastern Tasmania.

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REFERENCES

Belica, M.E., Tohver, E., Pisarevsky, S.A., Jourdan, F., Denyszyn, S. and George, A.D., 2017, Middle Permian paleomagnetism of the Sydney Basin, Eastern Gondwana: Testing Pangea models and the timing of the end of the Kiaman Reverse Superchron: Tectonophysics, 699, 178–198.

Briden, J.C., 1967, Secondary magnetisation of some Palaeozoic rocks from Tasmania: Papers and Precedings of the Royal Society of Tasmania, 101, 43–48.

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., 2015, A new geodynamic model for Cambrian Tasmania/Australian East Gondwanaland – continent–continent collision above doubly divergent Dundas Trough subduction zones: in Siégel, C., Verdel, C., and Rosenbaum, G. (eds.), Riding the Wave, GSA Specialist Group in Tectonics and Structural Geology Confernece, Caloundra, Queensland, November 2015, Geological Society of Australia Abstract Series No. 113, pp. 21–22.

Cayley, R., Musgrave, R., and Preiss, W., 2012, South-directed oroclinal folding in the Lachlan Fold Belt: a solution to apparent Ordovician–Early Silurian complexity: Program and Abstracts, SGTSG biennial conference, Waratah Bay, Australia, Geological Society of Australia Abstracts 102, 19–21.

Cayley, R.A., Taylor, D.H., Vandenberg, A.H.M., and 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 Sciences, 49, 225–254.

Delisle, G., Rolf, C., and Findlay, R.H., 1993, The palaeomagnetic record of selected Tasmanian rock units: Mineral Resources Tasmania, Report 1993/08, pp. 1–7.

Dunlop, D.J., 2003, Stepwise and continuous low-temperature demagnetization: Geophysical Research Letters, 30, 1582, doi:10.1029/2003GL017268.

Kirschvink, J.L., 1980, The least-squares line and plane and the analysis of palaeomagnetic data: Geophysical Journal of the Royal Astronomical Society, 62, 699–718.

McElhinny, M.W., Powell, C.McA., and Pisarevsky, S.A., 2003, Paleozoic terranes of eastern Australia and the drift history of Gondwana: Tectonophysics, 362, 41–65.

McFadden, P.L., 1990, A new fold test for palaeomagnetic studies: Geophysical Journal International, 103, 163–169.

McLean, M.A., Morand, V.J., and Cayley, R.A., 2010, Gravity and magnetic modelling of crustal structure in central Victoria: what lies under the Melbourne Zone?: Australian Journal of Earth Sciences, 57, 153–173.

Moore, D.H., Betts, P.G., and Hall, M., 2013, Towards understanding the early Gondwanan margin in southeastern Australia: Gondwana Research, 23, 1581–1598.

Moore, D.H., Betts, P.G., and Hall, M., 2015, Fragmented Tasmania: the transition from Rodinia to Gondwana: Australian Journal of Earth Sciences, 62, 1–35.

Moresi, L., Betts, P.G., Miller, M.S., and Cayley, R.A., 2014, Dynamics of continental accretion: Nature, 508, 245–248.

Musgrave, R.J., 2015, Oroclines in the Tasmanides: Journal of Structural Geology, 80, 72–98.

Schmidt, P.W., 1982, Linearity spectrum analysis of multi-component magnetizations and its application to some igneous rocks from south-eastern Australia: Geophysical Journal of the Royal Astronomical Society, 70, 647–665.

Schmidt, P.W., and Embleton, B.J.J., 1981, Magnetic overprinting in southeastern Australia and the thermal history of its rifted margin: Journal of Geophysical Research, 86, 3998–4008.

Schmidt. P.W., Lackie, M.A., and Anderson, J.C., 1995, Palaeomagnetic evidence for the age of the Lapstone Monocline, NSW: Australian Coal Geology, 10, 14–19.

Van der Voo, R., 2004, Paleomagnetism, oroclines, and growth of the continental crust: GSA Today, 14, 4–9.