Late Mesozoic strike-slip faulting in Tasmania

R. F. BERRY

CODES, University of Tasmania, Private Bag 79, Hobart, Tas 7001, Australia

INTRODUCTION

The Mesoproterozoic basement of Tasmania is overlain by a Neoproterozoic passive margin sequence (Halpin et al. 2014). A Cambrian arc–continent collision (Stacey & Berry 2004) was followed by extensive post collisional magmatism. In the Ordovician to early Devonian, shallow-water sedimentation dominated across western Tasmania, while a turbidite succession built rapidly across eastern Tasmania. These sequences were deformed during a Devonian orogeny associated with extensive granite intrusion. In the latest Carboniferous, deposition began in the Tasmania Basin. The upper Carboniferous–Permain glacimarine sedimentary rocks are overlain by Triassic non-marine sandstones. A large volume of tholeiitic dolerite intruded the Tasmania Basin during the Middle Jurassic. Extensive latest Jurassic–Early Cretaceous and Paleocene extension produced several small basins. Fission track ages across Tasmania (Kohn et al. 2002; Figure 1) indicate much more extensive denudation in south and west Tasmania than the north and east, since 250 Ma. In particular, the southwest has had more than 2 km of erosion since 90 Ma, while in the northeast denudation has ~1 km since 130 Ma. The peak Cretaceous temperature of the rocks now on the surface is much higher in the southwest.

A rift system developed south of Australia in the Jurassic (e.g. Vevers et al. 1991). Late Jurassic–Early Cretaceous rifting propagated from west to east. Ultra-slow northwest–southwest spreading continued from 128 Ma until 83 Ma (Jacobs & Dyment 2014). Regional north–south shortening in the Cenomanian (ca 95 Ma; Miller et al. 2002) resulted in folding of Lower Cretaceous sedimentary rocks in what is now the Otway Ranges (Figure 1) and uplift over most of southeast Australia (e.g. Kohn et al. 2002). Uplift also occurred across the Transantarctic Mountains before 94 Ma (Jacobs & Dyment 2014). At about 83 Ma, the spreading direction on the southern margin of Australia changed to a north-south vector. At 60 Ma, the western South Tasman Rise detached from the Antarctic margin and became part of the present South Tasman Rise (Royer & Rollet 1997). Fast spreading, along the southern margin of Australia, began at 43 Ma.

The aim of this paper is to consider structural evidence for a strike-slip fault episode recorded in the Jurassic dolerite of Tasmania (Figure 2). Permian and Mesozoic rocks in Tasmania are strongly faulted but with the most obvious offsets related to normal fault movements during Cenozoic extension (Stacey & Berry 2004). Evidence of pre-Jurassic compressional tectonics was reported at Zeehan (Blissett 1962) and at Maydena (Dunster 1981). However, the first evidence of late Mesozoic strike-slip faulting was noted in the Hobart area (Berry & Banks 1985). Since this work, a survey of fresh exposures (road cuttings and quarries) of Jurassic dolerite of Tasmania (Figure 2). Permian and Mesozoic rocks in Tasmania are strongly faulted but with the most obvious offsets related to normal fault movements during Cenozoic extension (Stacey & Berry 2004). Evidence of pre-Jurassic compressional tectonics was reported at Zeehan (Blissett 1962) and at Maydena (Dunster 1981). However, the first evidence of late Mesozoic strike-slip faulting was noted in the Hobart area (Berry & Banks 1985). Since this work, a survey of fresh exposures (road cuttings and quarries) of Jurassic dolerite (ca 180 Ma; Figure 3; Everard et al. 2014), Cretaceous syenite (ca 100 Ma; McDougall & Leggo 1965) and Parmeener Supergroup (upper Carboniferous to Triassic) was carried out across the whole of Tasmania. The preservation of fault striations within the Parmeener Supergroup is poor and, while the new data support the findings reported in Berry & Banks (1985), little additional detail was found. In contrast, the dolerite is well exposed in fresh cuttings and quarries throughout Tasmania, and fault striations provide a record of late Mesozoic faulting dominated by dextral west-northwest–east-southeast-striking faults and sinistral north–south-striking faults. This fault association indicates compression from the NNW. Indirect evidence suggests these structures formed during the Cenomanian (ca 95 Ma) inversion in the Otway and Bass basins, and are probably part of the crustal shortening that formed the Transantarctic Mountains.

KEY WORDS: Cretaceous, fault striation, Tasmania dolerite, strike-slip.
METHODS

Major fault systems produce a fracture pattern that reflects the stress conditions during faulting. Provided sufficient fault striations associated with this fracture pattern are exposed it is possible to interpret the orientation of the local stress field during faulting and to build up a picture of the stress trajectory over a larger area. An intuitive appreciation of the fault pattern is possible where the faulting history is simple but a more objective comparison can be made using numerical methods to model the stress direction. Sperner & Zeigal (2010) provided a review of the applicable methodology. In the Tasmanian dolerite, a single generation of fault striations was recognised by the mineral association. The sense of movement of a third of the striated faults in this study were directly determined using the methods described by Petit (1987). For the remainder, the movement sense was inferred from the sense of movement on faults of similar orientation (within 10°) in the same outcrop. The principal stress orientations were calculated for each site using the numerical method of Etchecopar et al. (1981). The measured fault slip data are included in the supplementary papers (Table A1).

RESULTS

Most fault striations on fractures in the dolerite are defined by chlorite–zeolite–calcite slickenfibres. Several different zeolite or calcite associations also occur in non-striated areas on fault planes and joints (Sutherland 1977). Chlorite was not found on joints. Another common feature of the dolerite is 10–30 cm wide clay zones that are partly filled with massive quartz–zeolite veins. Only one example of these zones was found with fault striations recognisable. A 30 cm wide clay zone at Lake Mackenzie spillway (Figure 3, location LM) contained cataclasite with strike-slip striations dominant.

Late normal sense fault striations were recognised within the dolerite at two localities. In both cases these
were grooves developed in clay gouge, indicating very different conditions from those operating during strike-slip faulting. The clay gouge zones offset micro-faults with strike-slip striations. Only at Grove (see below) were normal fault striations found that were defined by chlorite–zeolite fibres in the dolerite. The major faults are smooth surfaced with little evidence for sense of shear except chlorite fibres behind rare asperities. Minor faults have variable morphology. The most useful criteria (Figure 4) in these rocks is the presence of fibres crystallising in the lee of asperities (Figure 4b) and the next most common set of criteria are PO criteria (of Petit 1987, Figure 4h). R criteria (RO and RM of Petit 1987, Figure 4c, e) were common at one site near Tyenna but less common at other sites. T criteria were exceedingly rare and were not used to identify the movement sense on these faults. Photographs of several typical surface features are shown in the supplementary papers (Figure A2).

PO criteria occur on fractures at a high angle (50–80°) to the inferred \(\sigma_1\) direction. These planes have no discernible displacement consistent with the origin for these structures expounded by Petit (1987) who argued that PO criteria develop on pre-existing joint surfaces where movement was extremely small. This is compatible with the observation here that PO is preserved on surfaces with low resolved shear stress at a high angle to \(\sigma_1\). In contrast, many slickenfibres nucleated at small ledges on faults oriented at 30–50° to the inferred \(\sigma_1\) direction, with only a few exceptions at higher angles. RM and RO tectoglyphs showed a wide range of orientations with RO restricted to faults containing fault breccia or cataclasite.

**Lower Pieman Road**

Striations were recorded from three large quarries 4, 5 and 7 km east of the Reece Dam (347100 mE 5375200 mN; 348100 mE 5375200 mN; 349600 mE 5375700 mN) in the northern part of the dolerite intrusion west of Zeehan (Figure 3, location a) in western Tasmania. The striations were defined by chlorite fibres with zeolite commonly present behind ledges.

The site is dominated by sinistral strike-slip faults (Figure 5a) with highly variable dextral faults and two oblique reverse striations with transfer type orientations (striations parallel to fault intersections; see Nieto-Samaniego & Alaniz-Alvarez 1997 for a review of kinematic constraints on intersecting faults). There is one large fault with 10 m of fault breccia exposed in these quarries. It dips 80° towards 043° with lineation pitching 18° SE. A few hundred metres west of this exposure there is an unexplained 250 m offset of the dolerite contact (Reed 2000) that is consistent with a dextral fault striking 135°.

**Figure 4** Tectoglyphs used to identify movement sense on faults (redrawn from Petit 1987). All diagrams drawn for top (missing) block moving to the right: (a) notation for elementary secondary fractures associated with a major (M) fault plane; (b) slickenfibres nucleating from irregularities on the fault surface; (c, e, g) faults surfaces dominated by R fractures; and (d, f, h) striated surface is a P fracture.
Figure 5 Lower hemisphere equal area projection of fault planes and movement directions from 12 sites across Tasmania. Locations for these sites are shown in Figure 3. Diagrams drawn with software of Yamaji & Sato (2012).
A few minor faults, at this locality, are parallel to the regional fault but most of the minor dextral faults are in P shear orientations. Only one dextral striation was detected in an R orientation. The sinistral faults range from typical conjugate orientations to R' orientations.

Zeehan

Further south, the same dolerite intrusion is exposed along the road from Zeehan to Granville Harbour and Reece Dam (Figure 3, location b). The striations reported here are from four road cuttings 14 to 17 km from Zeehan. (353000 mE 5370000 mN; 352500 mE 5369600 mN; 352000 mE 5369300 mN; 351700 mE 5369400 mN; 351400 mE 5368900 mN). The striations are largely defined by chlorite with minor zoelite and purple quartz. By far the most common striations have PO movement criteria with a few showing fibres of chlorite and quartz from ledges. RM criteria are rare (two sinistral surfaces). The faults fall into a discrete northeast-striking sinistral group and two discrete dextral orientations, east and southeast striking (Figure 5b). Based on the interpretation at site a, the major dextral fault orientation is 135° in western Tasmania, the southeast-striking faults are parallel to these larger scale faults and the east-striking minor faults are in P shear orientations (Figure 4a). This is compatible with the dominance of PO criteria on most microfaults at this site.

Butlers Gorge

Twenty-five striation orientations were recorded from a small quarry at Butlers Gorge (439800 mE 5319600 mN; Figure 3, location c). The striations were defined by fibrous chlorite and zoelite. The most common movement criteria were chlorite and zoelite fibres crystallised on fault steps. All measured striations were related to strike-slip movement (Figure 5c) with sinistral striations dominant on steep surfaces striking 020° and dextral striations on surfaces striking 080°, 100° and 120°. This is similar to the Lower Pieman Road site.

Oatlands

Ten striations (Figure 5d) were measured in a road cutting 3 km south of Oatlands (528300 mE 5314100 mN; Figure 3, location d). The striations are mainly chlorite fibres in a PO arrangement. The dextral faults strike southeast, while the sinistral surfaces strike north–south. The dominant fault orientation in this area is apparently the southeast-striking dextral faults but no regional structures in this orientation are known.

Sandfly

At a major road cutting in dolerite 1 km west of Sandfly (514300 mE 5241100 mN; Figure 3, location e), 32 fault striations were measured. The dominant fault mineral here is chlorite with minor calcite and pyrite. Many of the surfaces are very rough and the recognition of movement sense was difficult. There are a number of PO surfaces but more commonly the chlorite fibres crystallised on extensional bridges. The roughest surfaces are on faults that strike at 045° and have PO criteria indicating mixed movement senses consistent with their very high angle to the inferred σ1 direction. The smoother dextral faults striking 100°–120° are interpreted as the major fault direction in this area (Figure 5e).

Port Arthur

Twenty-one striations were measured from a small road cutting 1 km west of Port Arthur (567600 mE 5223200 mN; Figure 3, location f). The striations are dominated by chlorite with minor fibrous oxide minerals and calcite. The interpretation of movement sense was difficult in this cutting. PO criteria were the most common and most surfaces had very little movement on them. Fault interactions suggest 110° striking faults are the most important through-going surfaces. The 160° dextral and 050° sinistral faults are interpreted as R and R' fractures (Figure 4a), respectively, related to these dominant faults. The dextral movement shown on Figure 5f for the two faults striking 070° is speculative and based on the calculated stress tensor for the other striations.

Tyenna River

Sixteen faults striations (Figure 5g) were measured from a railway cutting 3 km west of Bushy Park (487500 mE 5274200 mN; Figure 3, location g). The cutting was weathered, but chlorite fibre veins were very common. There are many RM surfaces, and the faults interact and offset each other. The location is dominated by dextral faults with an average strike of 080°. RM criteria are common on most dextral faults. A few conjugate sinistral faults were measured. The fault pattern is anticlockwise of the orientation patterns recognised in the six locations discussed above, and this feature is common to locations g to j, which are mainly from southeast Tasmania.

Risdon Brook Dam

Twenty-five striations were measured from a dolerite quarry at Risdon Brook Dam (526800 mE 5262100 mN; Figure 3, location h) near Hobart. The locality is dominated by dextral faults (Figure 5h). The shear sense indicators were RO, RM and chlorite fibres behind ledges. Chlorite dominates over zoelite. Well-polished smooth fault surfaces strike between 075° and 095°. The quarry is 200 m south of a regional fault striking 120°, which has a post-dolerite dextral offset of 200 m (Leaman 1972). On this basis most of the measured dextral faults vary from the major fault orientation around to the P fracture orientation (cf Figure 4b). Only two measured faults are in the R fracture orientation, and both are rough surfaces with ambiguous movement indicators.

Proctors Road

Twenty-seven striations were recorded from a quarry on Proctors Road, Hobart (525400 mE 5249200 mN; Figure 3, location i). The striations were mainly defined by chlorite with minor fibrous zeolite. A few striations had
chlorite from ledges but PO criteria are also present. Striations at the Proctors Road quarry are dominated by sinistral strike-slip faults striking north–south (Figure 5i). A few conjugate dextral strike-slip faults were present. This exposure is the best example in this data set of sinistral faults dominating over dextral faults. The quarry lies near the southern termination of the Cascades Fault Zone (170° strike). The Cascades Fault Zone was the major bounding fault for the Cenozoic extension that formed the Derwent Graben (Leaman 1976) and has not previously been identified as having any strike-slip movement. Kinematic data from this quarry provide evidence that the Cascades Fault Zone had an earlier history as a sinistral fault.

Huonville
The Huonville data come from two quarries: 14 striations are from Jackson Road south of Huonville (500000 mE 5227100 mN) and 4 sinistral striations are from a quarry 1 km southeast of Huonville (504700 mE 5234700 mN). These two sites, 8 km apart (Figure 3, location j), are considered together because of the close similarity in fault orientations. They have a very simple pattern of faults with 340° striking sinistral and 070° striking dextral faults. Striations are chlorite fibres with minor zeolite.

The lower reach of the Huon River is a very straight 10 km long segment trending 210° that forms a regional lineament on the digital elevation model of Tasmania. At the northern edge a dolerite dyke has an apparent sinistral offset across the river of about 500 m (Farmer 1981). No fault has been reported along the lower reach of the Huon River but the river morphology and the data here together suggest that the river may follow a Mesozoic sinistral fault zone. If this interpretation is correct, all but one of the fault striations measured are in Riedel orientations relative to this fault.

Southern Outlet
A major cutting on the Southern Outlet (525300 mE 5247500 mN; Figure 3, location k) south of Hobart is dominated by an exposed thrust surface (300 m by 30 m). The fault plane was the release surface for a major rock slide during road construction in 1990. Twenty-two striations defined by chlorite with minor zeolite were recorded; PO criteria and fibres nucleating on ledges are common. The site is dominated by a gently west-dipping fault surface, which was covered in fibres recording a reverse movement. Five measured dextral strike-slip planes have movement directions parallel to this surface and are interpreted as transfer faults for the thrust movement (cf. Nieto-Samaniego & Alaniz-Alvarez 1997). The remaining strike-slip striations are symmetrical around the thrust movement and are consistent with the same σ1 as can be inferred from the thrust orientation. The σ1 calculated for this site trends 296° and is anticlockwise of all other sites measured. The thrust exposed here is interpreted as a compressional bridge or horsetail splay at the southern termination of the Cascades Fault Zone.

Grove
Road cuttings north of Grove (508700 mE 5241700 mN; Figure 3, location l) host normal fault striations. This is the only area in which northwest-striking faults have dip-slip striations defined by chlorite fibres (Figure 5l). The cuttings were older and more weathered than other sites measured and the sense of shear was difficult to determine. Only two of the striated fractures were recognisably normal in movement sense based on the chlorite fibres behind ledges. However, small normal faults in the hornfelsed mudstones adjacent to the dolerite have the same orientation, so the interpretation here is that all the dip-slip striations record normal displacement. For consistency, only striations from fault planes in dolerite are shown in Figure 5. The sinistral and dextral faults at this locality are interpreted as transfer faults with movements controlled by the larger scale normal faults. The geology near this site provides no clues as to why normal faulting dominated at this locality.

DISCUSSION
Fault striations were recorded from outcrops of dolerite in road cuttings and quarries throughout Tasmania (Figure 3). The faults were dominated by strike-slip displacement (Figure 5) in which north–south striking faults are invariably sinistral and west-northwest–east-southeast-striking faults are dextral. The fields of dextral and sinistral faults overlap at strikes of 045°, which is interpreted here as the result of the inclusion of first- and second-order P fractures in the study. Minor faults with this strike are commonly very rough with many asperities in comparison with the smooth surfaces of the primary fractures. Faults at six sites (a–f) have sinistral faults striking 000°–045° and dextral faults mainly in the range 090°–130°. In contrast, four locations in southeast Tasmania (g–j) have sinistral faults mainly striking 180°–190° and dextral faults striking 060°–100°.

The fault striation data can be explained by a single deformational event. The principal stress orientations were estimated at each site (Table 1) using the numerical method of Etchecopar et al. (1981). All solutions, except the Southern Outlet, indicate σ3 trends northeast–southwest (Figure 6). All except the Grove site require σ1 trending northwest–southeast. However, the results can be readily grouped in to those sites in southeast Tasmania with σ1 trending ~125° and those throughout the rest of Tasmania with σ1 near 155° (Figure 6). The other site at Grove is also consistent with a regional northeast-extension direction (Figure 6). The simplest interpretation is that there is a regional swing in the Cretaceous shortening direction from north-northwest to northwest across Tasmania.

The faults are found in dolerites that have a crystallisation age of ca 180 Ma (Everard et al. 2014). An example of geometricaly similar strike-slip striations was found in an outcrop of the Cretaceous syenite near Huonville (Silver Hills Road, 501500 mE 522900 mN). At this outcrop, a sinistral fault and associated minor reverse faults (Figure 7) are overprinted by normal faults typical of the later (Cenozoic) extensional event. The sinistral fault surface is parallel to a less common orientation found in
the dolerites. Although these striations do not have the same mineral suite seen on the faults in dolerite, this may simply reflect the influence of wall-rock composition on vein mineralogy. Accordingly, the sinistral fault in the syenite may indicate that the strike-slip faulting in Tasmania postdates intrusion of the syenite intrusion at ca 100 Ma. Other outcrops of the syenite have extensional fault striations but no other structures that might correlate with the strike-slip faulting in the dolerite were found.

The strike-slip striations are overprinted by normal fault striations in the Derwent Graben (Berry & Banks 1985) and throughout south and west Tasmania. The Derwent Graben formed as two linked structures containing a few hundred metres of Paleocene sediment (Stacey & Berry 2004). Thus, the faulting event described here is older than 55 Ma.

All the striations reported here come from the south and west of Tasmania (Figure 3). In these areas striations were found in one-third of the fresh dolerite exposures. In contrast, of the 30 excellent exposures studied, in the north and east of Tasmania only a few weak striations were found at two localities. Deeply weathered clay zeolite zones do occur in the north but are less common. At Lake Mackenzie (Figure 3) the freshest exposure of one of these zones had recognisable strike-slip striations.

| Location          | Plunge | Trend | Plunge | Trend | σ3 Plunge | Trend | R          | Error | Data no. |
|-------------------|--------|-------|--------|-------|------------|-------|------------|-------|----------|
| Pieman Road       | 7 (14) | 166 (11) | 82 (14) | 325 (77) | 3 (9) | 075 (10) | 0.6 (0.5) | 14 | 28 32 |
| Zeehan            | 11 (31) | 158 (8) | 79 (31) | 347 (41) | 2 (7) | 249 (9) | 0.8 (0.3) | 8 | 39 44 |
| Butlers Gorge     | 9 (14) | 317 (11) | 73 (10) | 196 (69) | 14 (14) | 49 (10) | 0.8 (0.4) | 9 | 13 14 |
| Oatlands          | 8 (9) | 344 (23) | 82 (9) | 164 (26) | 0 (20) | 254 (25) | 0.2 (0.4) | 8 | 10 10 |
| Sandfly           | 2 (1) | 152 (12) | 87 (63) | 288 (6) | 2 (91) | 062 (13) | 0.1 (0.9) | 7 | 25 32 |
| Port Arthur       | 4 (9) | 332 (20) | 83 (7) | 209 (60) | 6 (6) | 063 (20) | 0.8 (0.8) | 10 | 18 21 |
| Tyenna            | 1 (5) | 122 (19) | 88 (9) | 354 (6) | 1 (8) | 212 (19) | 0.3 (0.5) | 5 | 16 16 |
| Risdon Brook      | 0 (34) | 315 (18) | 84 (8) | 045 (6) | 6 (8) | 225 (20) | 0.9 (0.7) | 8 | 25 25 |
| Proctors Rd       | 5 (4) | 131 (14) | 76 (68) | 021 (6) | 13 (73) | 222 (18) | 0.1 (0.3) | 8 | 24 27 |
| Huonville         | 8 (10) | 113 (27) | 80 (9) | 337 (6) | 7 (20) | 204 (28) | 0.4 (0.6) | 5 | 14 18 |
| Southern Outlet   | 1 (6) | 296 (12) | b      | b      | b      | b      | 0.0 (0.3) | 8 | 17 22 |
| Grove             | 71 (11) | 122 (6) | 11 (10) | 306 (42) | 1 (25) | 216 (38) | 0.0 (0.2) | 8 | 13 15 |

Trend not significant because of steep plunge.
Stress direction not defined owing to error in R.
Standard errors on plunge and trend are shown in parentheses.

Figure 6 Calculated stress orientations for 12 sites across Tasmania. Lower hemisphere equal area projection.

Figure 7 Early fault striations measured in the Cygnet syenite. Lower hemisphere equal area projection. Diagram drawn with software of Yamaji & Sato (2012).
in a clay-altered cataclasite zone. The interpretation favoured here is that north and east Tasmania were affected by this event but under conditions that did not allow the synkinematic crystallisation of chlorite and zeolite on the fault surfaces. Kohn et al. (2002) concluded that northern Tasmania has a different uplift and cooling history than southern Tasmania and showed that the present surface rocks in northeast Tasmania cooled below 100°C around 130 Ma while southern Tasmania was above 100°C until after 90 Ma. The approximate boundary between the two denudation domains (as shown on figure 6 in Kohn et al. 2002) is reproduced as a dashed line on Figure 3. Almost all the good exposures of striations found in dolerite are from south of this line in rocks that were still buried deeper than 2 km at 90 Ma. The Ca-zeolite + chlorite mineralogy of these striations is consistent with temperatures around 100°C, and the variation in uplift history demonstrated by Kohn et al. (2002) provides a good explanation for their distribution if the striations were formed between 130 Ma and 90 Ma.

The most likely environment for the formation of the strike-slip faults in Tasmania is the period of northwest–southeast compression in the Cenomanian (100–95 Ma) that has been recognised in the Otway Basin (Miller et al. 2002; Krassay et al. 2004). This period is consistent with the absolute constraints (<180 Ma, >55 Ma) and with strike-slip striations found in the Cygnet Syenite. It fits well with the cooling history for southern Tasmania. No other northwest-compressional event has been reported in this region between 180 Ma and 55 Ma.

Cretaceous reconstructions for Gondwana place Tasmania very close to Northern Victoria Land (Figure 1) at 95 Ma. Jacob & Dyment (2014) argued the Transantarctic Mountains were uplifted before 94 Ma in a northwest–southeast shortening event similar in orientation to that reported here for Tasmania. Further south, a dextral transtensional zone in Marie Byrd Land is well dated at 95 Ma (Siddoway et al. 2004, 2005; McFadden et al. 2010) and this correlates well with the Cenomanian inversion in Tasmania and the Otway Basin. McDonald et al. (2013) reported extensive areas of uplift (1–2 km) in South Australia between 100 Ma and 80 Ma, which may also correlate with these events.

A very similar style of strike-slip faulting has been recognised in the southern Sydney Basin (Peacock & Shepherd 1997) but this event is probably older (163–111 Ma) than the event documented here (Och et al. 2009, 2014). Similarly, sinistral Mesozoic faulting along the North Pine Fault system in southeast Queensland (Babaahmadi & Rosenbaum 2014a) occurred during northwest–southeast compression but the weight of evidence suggests it is older than 200 Ma. More extensive strike-slip faulting in Queensland (Babaahmadi & Rosenbaum 2014b) occurred after 30 Ma. It appears the Cretaceous northwest–southeast shortening event was restricted to the southern margin of Australia and the nearby parts of Antarctica.

**SUMMARY**

A widespread strike-slip deformation event occurred across western and southern Tasmania in the late Mesozoic. Northwest–southeast compression produced north–south-striking sinistral and west-northwest–east-southeast-striking dextral faults. This event has been recognised from minor fault populations in artificial exposures of Jurassic dolerite. There is some evidence that regional-scale faults with strike-slip offsets of a few hundred metres were active during this event. The most likely interpretation is that these faults were formed during a large-scale inversion and uplift event that extended across the Transantarctic Mountains, Otway Basin and southern South Australia.

**ACKNOWLEDGEMENTS**

This project was carried out with support from the University of Tasmania. I wish to thank R. Scott and J. Mulder for providing comments on early drafts of the manuscript, and C. Siddoway and A. Babaahmadi for their constructive reviews.

**DISCLOSURE STATEMENT**

No potential conflict of interest was reported by the authors.

**SUPPLEMENTARY PAPERS**

Table A1 Summary of fault striation data used in this paper.

Figure A2 Example photographs of fault striations and fault surfaces. (a) PO fault striations (dextral). Field of view 15 cm wide. (b) PO fault striation (sinistral). Standard paper clip for scale. (c) RM striated surface (dextral). Geological hammer for scale. (d) Detail on lunate fractures on same RM surface (dextral) Figure A2c. Field of view 40 cm wide. (e) RO striated surface (dextral). Standard paper clip for scale. (f) Chlorite fibres attached to surface (sinistral). Field of view 3 cm wide. (g) Chlorite fibres attached to surface (sinistral). Field of view 10 cm wide. (h) Normal fault with grooves in clay matrix cutting across striated surfaces showing the strike slip features described in this paper.

**REFERENCES**

Babaahmadi A. & Rosenbaum G. 2014a. Late Mesozoic and Cenozoic wrench tectonics in eastern Australia: Insights from the North Pine Fault System (southeast Queensland). *Journal of Geodynamics* 73, 83–89.

Babaahmadi A. & Rosenbaum G. 2014b. Late Cenozoic intraplate faulting in eastern Australia. *Journal of Structural Geology* 69, 59–74.

Berry R. F. & Banks M. R. 1985. Striations on minor faults and the structure of the Parmeener Supergroup near Hobart, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 119, 23–30.

Blissett A. H. 1962. Zeehan, Tasmania. Geological Atlas 1 mile series Explanatory Notes, Department of Mines, Tasmania. Hobart Tas.

Dunster J. N. 1981. Some structural complications of the Parmeener Supergroup, Tasmania. University of Tasmania Honors thesis (unpublished). Hobart Tas.
Mesozoic strike-slip faulting, Tasmania

ETCHEOPAR A., VASSEUR G. & DAGNIERES M. 1981. An inverse problem in microtectonics for the determination of stress tensors from fault striation analysis. *Journal of Structural Geology* 3, 51–65.

EVERARD J. L., LEAMAN D. E., CALVER C. R. & MORRISON K. C. 2014. Jurassic dolerite and associated minor lavas and sedimentary rocks. In: Corbett K. D., Quilty P. G. & Calver C. R. eds. *Geological Evolution of Tasmania*, pp. 385–407. Geological Society of Australia Special Publication 24, GSA (Tasmanian Division) Hobart Tas.

FARMER N. 1981. Kingborough, Tasmania. Tasmanian Department of Mines Geological Atlas 1:50,000 Series Sheet 8311N. Hobart Tas.

HALPIN J. A., JENSEN T., MCGOLDRICK P., MEFFRE S., BERRY R. F. & EVERARD R. & Lang S. C. eds. 2000. Sheet 3437 Stringer, Digital Geological Atlas 1:25,000 Scale Series. Mineral Resources Tasmania, Hobart Tas.

JACOB J. & DYMENT J. 2014. Early opening of Australia and Antarctica: New inferences and regional consequences. *Tectonophysics* 636, 244–256.

KOEH N. P., GLEADOW A. J. W., BROWN R. W., GALLAGHER K., O’SULLIVAN P. B. & FOSTER D. A. 2002. Shaping the Australian crust over the last 300 million years: insights from fission track thermotectonic imaging and denudation studies of key terranes. *Australian Journal of Earth Sciences* 49, 697–717.

KRASAV A. A., CATHER D. L. & RYAN D. J. 2004. A regional tectonostratigraphic framework for the Otway Basin. *In: Boult P. J., Johns D. R. & Lang S. C. eds. Eastern Australasian Basins Symposium II*, pp. 97–116. Petroleum Exploration Society of Australia, Special Publication, Adelaide SA.

LEAMAN D. E. 1972. Hobart, Tasmania. Tasmanian Department of Mines Geological Atlas 1:50,000 Series Sheet 8312S. Hobart Tas.

LEAMAN D. E. 1976. Hobart, Tasmania. Tasmanian Department of Mines Geological Atlas 1:50,000 Series Explanatory Report for Sheet 8312S, 116 pp. Hobart Tas.

MACDONALD J. D., HOLFORD S. P., GREEN P. F., DUNNY I. R., KING R. C. & BACKE G. 2013. Detrital zircon data reveal the origin of Australia’s largest delta system. *Journal of the Geological Society* 170, 3–6.

MCDougall I. & LEEGO P. J. 1965. Isotopic age determinations on granitic rocks from Tasmania. *Journal of the Geological Society* of Australia 12, 285–332.

McFADDEN R. R., SIDDOWA YC. S., TEYSSIER C. & FANNING C. M. 2010. Cretaceous oblique extensional deformation and magma accumulation in the Fosdick Mountains migmatite-cored gneiss dome, West Antarctica. *Tectonics* 29, TC0902. doi:10.1029/2009TC002492.

MILLER J. M., NORVIK M. S. & WILSON C. L. 2002. Basement controls on rifting and the associated formation of ocean transform faults—Cretaceous continental extension of the southern margin of Australia. *Tectonophysics* 339, 131–155.

Nieto-Samaniego A. F. & ALANES-ALVAREZ S. A. 1997. Origin and tectonic interpretation of multiple fault patterns. *Tectonophysics* 270, 197–206.

OCHE D. J., OFFLER R. & ZWINGMANN H. 2014. Constraining timing of brittle deformation and fault gouge formation in the Sydney Basin. *Australian Journal of Earth Sciences* 61, 337–350.

PETIT J. P. 1987. Criteria for the sense of movement on fault surfaces in brittle rocks. *Journal of Structural Geology* 9, 597–608.

R E D A. A. (compiler) 2000. Sheet 3437 Stringer, Digital Geological Atlas 1:25,000 Scale Series. Mineral Resources Tasmania, Hobart Tas.

ROVER J. Y. & ROLLEY N. 1997. Plate-tectonic setting of the Tasmanian region. *Australian Journal of Earth Sciences* 44, 543–560.

Siddoway C. S., BALDWIN S., FITZGERALD G., FANNING C. M. & LUYENDYK B. P. 2004. Ross Sea mylonites and the timing of intracontinental extension within the West Antarctic rift system. *Geology* 32, 57–60.

Siddoway C. S., SANS III L. C. & ESSER R. 2005. Kinematic history of Marie Byrd Land terrane, West Antarctica: Direct evidence from Cretaceous mafic dykes. *In: Vaughan A., Leat P. & Pankhurst R. J. eds. Terrane processes at the margin of Gondwana*, pp. 417–438. Geological Society of London Special Publication 246, London UK.

S PERRIN B. & ZEGLAL P. 2010. A plea for more caution in fault–slip analysis. *Tectonophysics* 482, 29–41.

STACY A. R. & BERRY R. F. 2004. The structural history of Tasmania: a review for petroleum explorers. *In: Boult P. J., Johns D. R. & Lang S. C. eds. Eastern Australasian Basins Symposium II*, pp. 151–162. Petroleum Exploration Society of Australia, Special Publication, Adelaide SA.

SUTHERLAND F. L. 1977. Zeolite minerals in the Jurassic dolerite of Tasmania: their use as possible indicators of burial depth. *Journal of the Geological Society of Australia* 24, 171–178.

V EEVERS J. J., POWELL C. M. & Roots S. R. 1991. Review of seafloor spreading around Australia. *Synthesis of the patterns of spreading*. *Australasian Journal of Earth Sciences* 38, 391–406.

YAMAJI A. & SATO K. 2012. A spherical code and stress tensor inversion. *Computers & Geosciences* 38, 164–167.

Received 25 November 2014; accepted 24 February 2015