New perspectives on Tasmanian geology

C. McA. POWELL
Geology Department, The University of Western Australia.

ABSTRACT

New information about the structure and sedimentary basin configuration in the southern Tasman Fold Belt confirms that the eastern Tasmania terrane is the on-strike continuation of the Melbourne Zone of Victoria. It represents a passive-margin to back-arc basin which was deformed and amalgamated with the western Tasmania terrane in the late Middle Devonian. The western Tasmania terrane has characteristics of both the western Lachlan Fold Belt and the Kanmantoo Fold Belt, and could be a largely exotic block lying across the junction between the two fold belts. The Precambrian "basement" of Tasmania, regarded for so long as firmly rooted to its mantle lithosphere, could be composed of thrust-bounded slices accreted to the Tasman Fold Belt initially in the Middle Cambrian during westward thrusting of the Kanmantoo Fold Belt over the platform margin in the Adelaide region. Renewed contraction in the Middle Devonian formed many of the present thrust contacts. These new ideas make it imperative that existing exploration philosophies and models are re-examined to take into account the thrust-fault geometry and the possible allochthonous nature of much of Tasmania.

INTRODUCTION

Tasmania occupies an important place in the geological framework of Australia, lying at the southern extension of the 1000-km wide Tasman Fold Belt, which occupies the eastern third of the continent (fig. 1). The Tasman Fold Belt is a largely Phanerozoic fold belt, with a history extending from the latest Precambrian, or beginning of the Cambrian, until the mid-Cretaceous, when the magmatic arc which lay along its eastern border for much of its history was rotated eastwards to its current position in the Tonga-Kermadec volcanic islands. The Tasman Sea grew in its wake.

Within the Tasman Fold Belt, there are three separate fold belts, each with a distinctive geological history, overlapping in time (fig. 2). The westernmost of these is the Kanmantoo Fold Belt, which began in the latest Precambrian or earliest Cambrian with deposition of quartzose clastics, mainly in deep-marine conditions. The Kanmantoo Fold Belt was deformed, intruded by granite, uplifted, and thrust westward onto the Australian craton from the Middle Cambrian to the earliest Ordovician (Preiss, 1987). The Lachlan Fold Belt, immediately to the east, contains marine sediments and volcanics of oceanic affinity, from at least the Middle Cambrian, and had a lively tectonic history until its stabilization in the mid-Carboniferous.

The Lachlan Fold Belt can be divided into two parts by a line running NNW from near Sale in Victoria, along the Mt Wellington fault zone, and thence along the western edge of the Wagga Metamorphic Belt (Powell *et al.*, 1990). To the west of this line, quartzose clastics deposited in mainly deep-marine conditions prograded from the south-west from the Early Ordovician to the Early Devonian. During the Ordovician, quartzose clastics derived from the south-west spread across the entire Lachlan Fold Belt as a submarine turbidite apron, but in the earliest Silurian the tectonic setting in the east changed dramatically. The mid-Silurian to mid-Devonian of the eastern Lachlan Fold Belt is dominated by massive outbursts of silicic volcanics, with underlying granitoid intrusives, abrupt facies changes caused by deposition in and adjacent to northerly-trending grabens, and local areas of contractional deformation (Powell, 1983, 1984*a*). The whole eastern Lachlan Fold Belt appears to have been a zone of transcurrence with local areas of transtension and transpression. The eastern and western Lachlan Fold Belt were reunited in the Middle Devonian when contractional deformation affected both parts, and the region rose above sea level. The final deformation in the mid-Carboniferous extended throughout Australia (Powell, 1984*a*, *b*), and was part of the world-wide deformation associated with the collision of Gondwanaland and Laurasia to form Pangea.

The easternmost fold belt, the New England Fold Belt, began in the Siluro-Devonian and was dominated by magmatic arcs which episodically stepped eastward throughout the next 300 million years. The final magmatic arc, which was active along the present coast of Queensland until the mid-Cretaceous, was extinguished when rifting began in the Tasman Sea about 95 million years ago (Veevers *et al.*, 1991). The New England Fold Belt contains most of the forearc asssemblages preserved in the Tasman Fold Belt, whereas the Lachlan and Kanmantoo fold belts have rock successions more typical of marginal-sea or back-arc settings.

Within this regional setting, Tasmania occupies a crucial position. First, it lies athwart the projected southern extension of the join between the Kanmantoo and Lachlan fold belts (fig. 1). This junction, postulated variously to lie along the Woorndoo fault zone adjacent to the eastern side of the Grampians in western Victoria (Baillie, 1985; Scheibner, 1985), or further east along the Avoca fault zone (Glen *et al.*, 1992), separates complexly multiply-deformed Cambrian rocks to the west from relatively simple, upright to locally overturned Devonian folds to the east (VandenBerg and Gray, 1992). Depending on where the tectonic boundary is placed, the Stawell gold mine lies either in the eastern Kanmantoo or the westernmost Lachlan Fold Belt.

Secondly, there is no known Precambrian exposed in the Tasman Fold Belt on mainland Australia, even though the presence of Precambrian sources at depth in some parts of the eastern Lachlan Fold Belt has been inferred from isotopic

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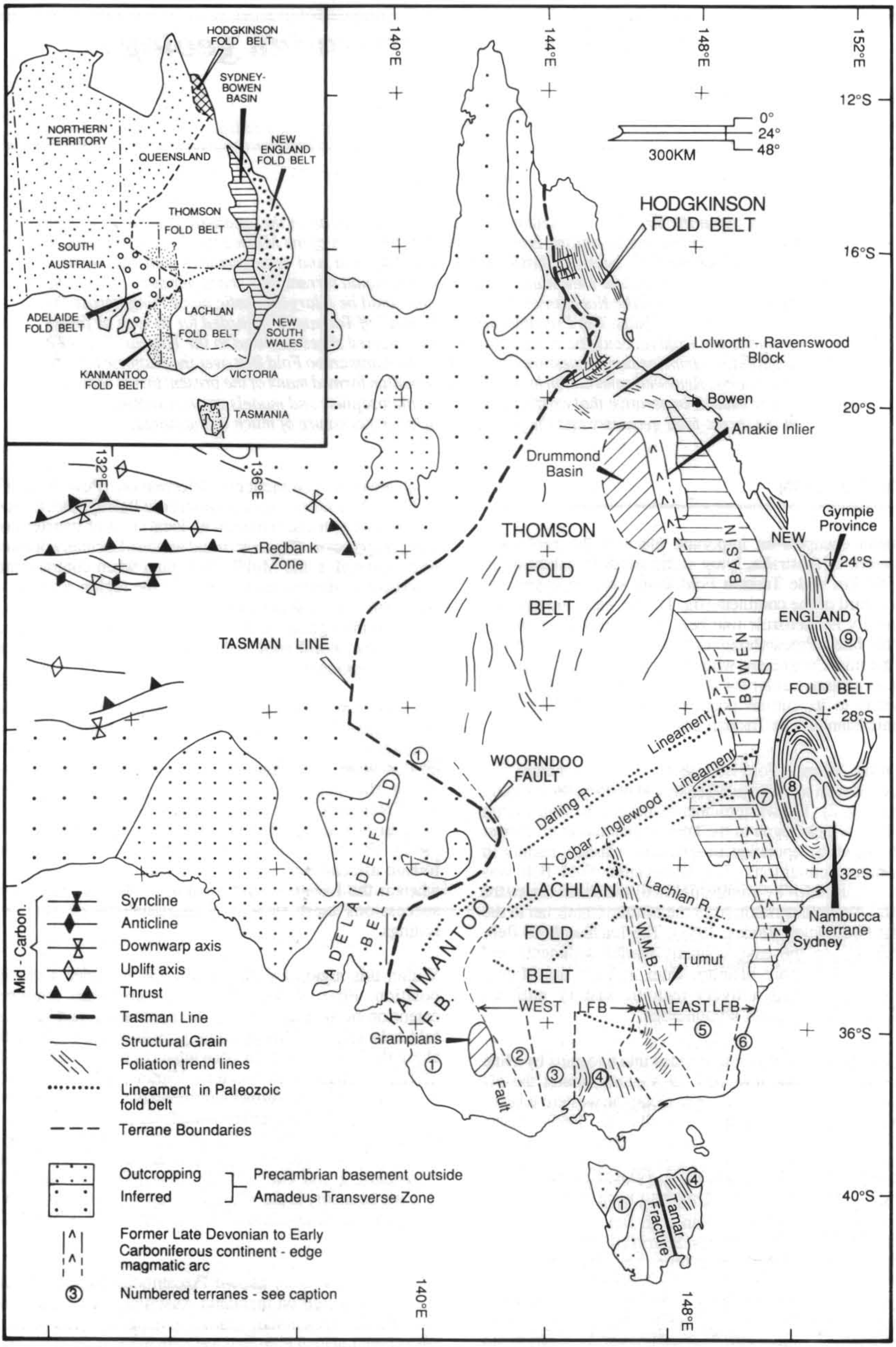

Figure 1

Tectonic sketch of eastern half of Australia showing the broad tectonic divisions of Tasman Fold Belt; modified from Powell *et al.* (1990, fig. 1).

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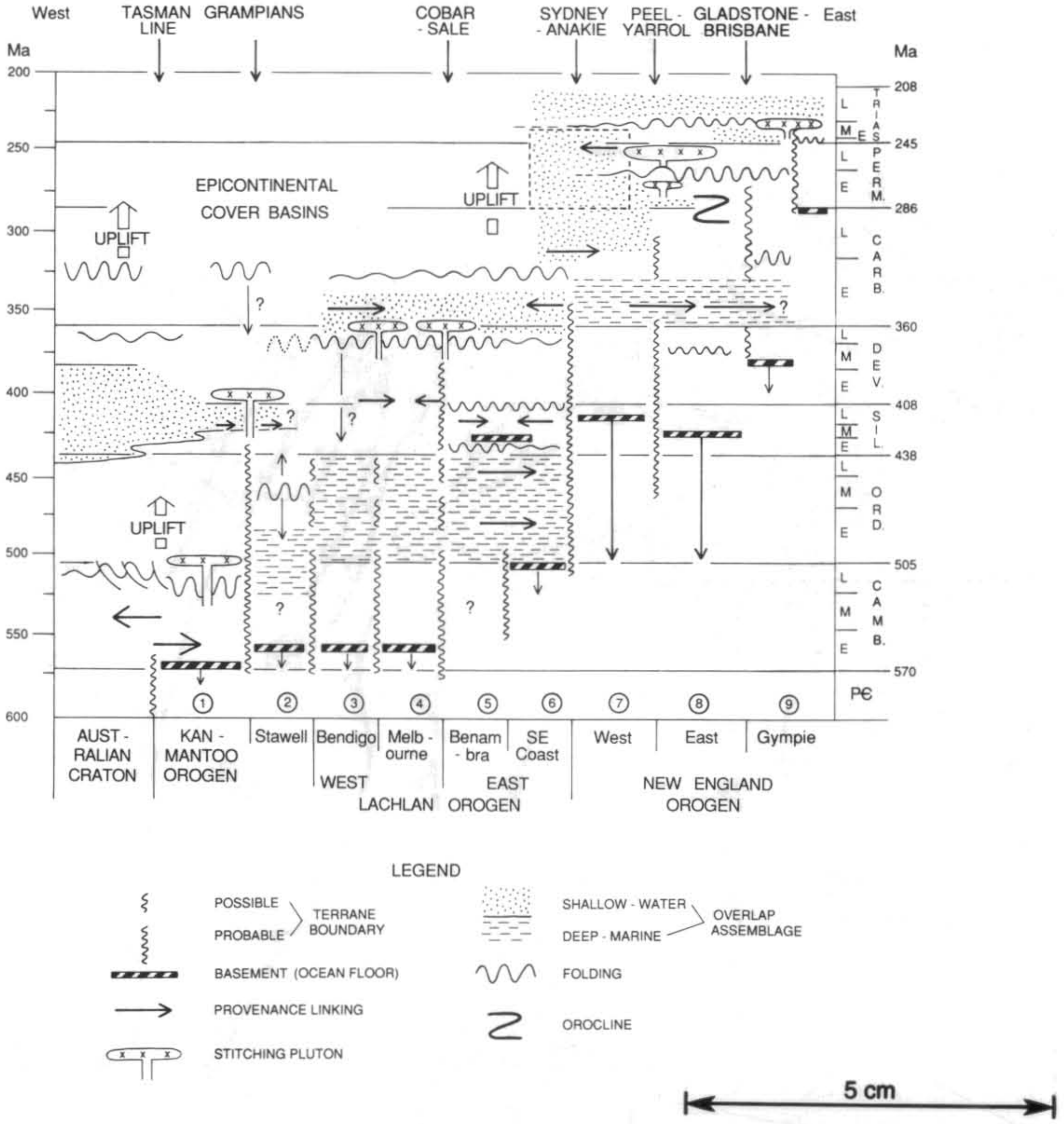

Figure 2

Time-space diagram for the southern Tasman Fold Belt (updated from Powell *et al.* 1990, fig. 2).

studies. The question thus arises of whether Tasmania is a window to the deeper levels of the Tasman Fold Belt.

In this paper, I outline some recent work in the southern Tasman Fold Belt, including growing recognition that thrust faults have played an important part in the tectonics, and raise the possibility that long-held ideas about Tasmania being cored by Precambrian rocks rooted to the Earth's mantle, may have to be revised. The implications for mineral prospectivity are profound.

TASMANIA'S GEOLOGICAL FRAMEWORK

Tasmania lies in the western half of the Tasman Fold Belt, with the western two-thirds of the island comprising Late to Upper Precambrian to mid-Palaeozoic rocks deposited in very varied tectonic settings. In contrast, the north-eastern third of the island comprises a remarkably uniform early Ordovician to Lower Devonian quartzose turbidite apron. These two parts, named the western and eastern Tasmania terranes (Banks and Baillie, 1989), have no clear connection until the Middle Devonian, when they are linked by deformation common to the whole of the southern Lachlan Fold Belt. Immediately afterwards, both eastern and western Tasmania were intruded by Upper Devonian to Lower Carboniferous granites (fig. 3–4).

The western Tasmania terrane comprises, from west to east (fig. 3), the relatively gently-deformed Upper Precambrian to Cambrian quartzose clastics, carbonates and mafic volcanics of the Smithton Basin and Rocky Cape region, bounded on the east by a highly deformed and metamorphosed linear zone, the Arthur Lineament. This passes eastward into Upper Precambrian quarztose turbidites of the Burnie region and Lower Cambrian turbidites, shales and mafic volcanics of the Crimson Creek Group. The latter succession is overlain by Middle and Upper Cambrian felsic, andesitic and minor mafic volcanics, and associated clastics of the Mt Read Volcanics, which passes up into Cambro-Ordovician clastics followed by Ordovician carbonates. Farther east, the central part of the island is occupied by multiply-deformed, mostly medium- to low-grade regional metamorphic Precambrian rocks of the Tyennan region. The Cambrian volcanic belt wraps around the northern end of this region, and there are two smaller areas of Precambrian rocks outcropping in the Forth and Badger Head regions (fig. 3). The eastern half of the western

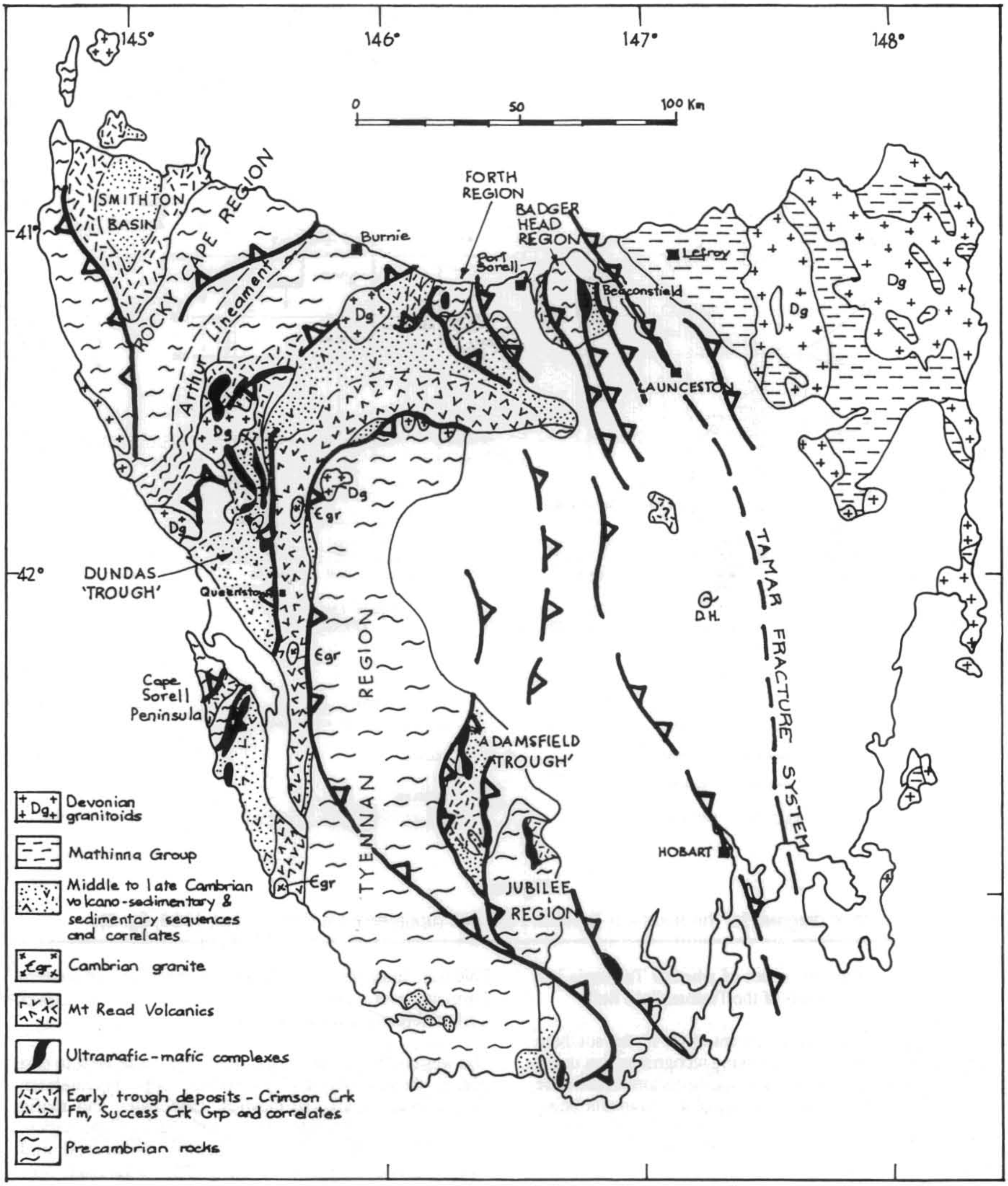

Figure 3

Simplified geological map of Tasmania showing tectonic elements, based on Corbett and Turner (1989, fig. 5.1) and Leaman *et al.*(1992, fig 2).

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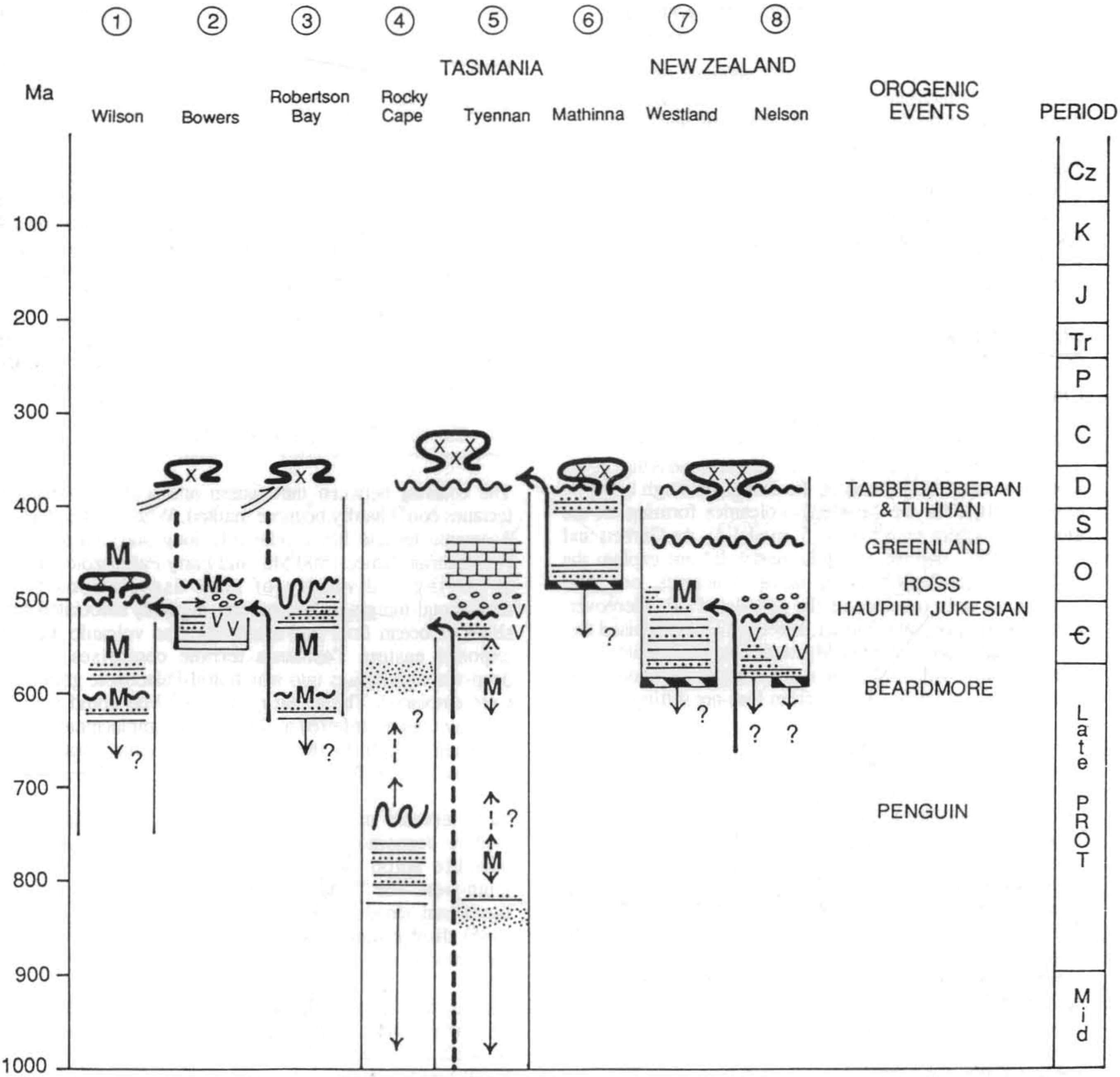

Figure 4

Terrane chart of the southern extension of the Tasman Fold Belt, from North Victoria land (terranes 1 to 3) through Tasmania (terranes 4 to 6) to New Zealand (terranes 7 and 8). Note that the western Tasmania terrane of Banks and Baillie (1989) is considered as two separate terranes, divided along the Arthur lineament, because of different tectonic histories prior to the end of the Cambrian. Most symbols as in Figure 2. Additionally, horizontal brick pattern = platform carbonate, M = age of metamorphism, v = volcanics.

Tasmania terrane is largely covered by flat-lying Permo-Triassic sediments and Jurassic dolerite, but there are some Cambrian rocks, with associated ultramafics, in the Adamsfield and Beaconsfield regions (fig. 3).

The eastern Tasmania terrane (fig. 3) contains a small area north-east of Launceston where a 1-km thick quartzose turbidite sheet is overlain by a thick black pelite, in part Lower Ordovician, which passes upward into widespread quartzose turbidites of the main part of the Mathinna Group (Powell *et al.* 1992*a*). The upper Mathinna Group, occupying much of north-eastern Tasmania, is Lower Devonian, and was deformed into NNW-trending folds and intruded by silicic melts in the late Early Devonian. The subsequent main granodioritic batholiths were emplaced in the Middle Devonian, prior to a south-westward-directed thrusting which amalgamated the eastern and western Tasmania terranes in the late Middle Devonian. Younger, in places stanniferous, granites were emplaced in the Late Devonian or Early Carboniferous, when granites were intruded throughout many parts of the island. Since the Early Carboniferous, the two terranes have remained welded together, and the only deformation has been mild extension along the Tamar Fracture System, and other faults, associated with emplacement of the Jurassic dolerite and subsequent stages of extension during Australia's breakup from Gondwanaland.

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PREVIOUS TECTONIC INTERPRETATIONS

Most earlier interpretations of the geology of Tasmania envisaged the tectonic setting of Lower Palaeozoic to have been narrow troughs developed between and within an extensive Precambrian basement (e.g. Williams, 1978, 1989). Williams (1978) considered the Precambrian to have formed "geanticlines" between adjacent troughs, the margins of which localised subsequent deformation. Precambrian regions were regarded as rigid blocks, implicitly rooted to the underlying mantle, which controlled the folding of the sediments caught between.

(a) Western Tasmania terrane

Considerable debate concerned the nature of the Mt Read volcanic belt and associated Dundas Group sediments, as outlined in the summary below precised from Corbett and Turner (1989). Early models (e.g. Campana and King, 1963; Corbett *et al.*, 1972) favoured the Dundas Trough being an ensialic rift, with the Mt Read Volcanics forming an arc along the eastern margin (fig. 5, model 1). As Corbett and Turner (1989) pointed out, this model did not explain the andesitic calc-alkaline nature of the volcanics, nor their location on only one side of the postulated rift. Moreover, Corbett (in Corbett and Turner, 1989, p.177) recognised that "... the association of high-Mg andesites (bonninites) and low-Ti basalts with ultramafic-mafic complexes [beneath the Dundas Group] is known only from fore-arc settings".

The second group of models tried to overcome these short-comings by postulating either a W-dipping (Solomon and Griffiths, 1972) or E-dipping (Solomon and Griffiths, 1974; Crook, 1980; Green 1984; Corbett and Lees, 1987) subduction zone in the Dundas 'Trough' (fig. 5, model 2). Problems associated with these models are the implied width of at least a few hundred kilometres for the ocean basin necessary to generate the Mt Read Volcanics by subduction, difficulty in locating the highly deformed subduction complex which would have developed in the trench, and the chemistry of the basalts (see above). Moreover, the models do not account for the presence of ultramafic rocks in the Adamsfield 'Trough' on the eastern side of the Tyennan block. A variant on the subduction model (fig. 5, model 3) suggested that the subduction zone lay east of the Tyennan block and dipped west, so that the Dundas 'Trough' formed during back-arc extension behind the Mt Read Volcanics (Solomon and Griffiths, 1974; Corbett, 1981; Varne and Foden, 1987). A perceived problem with this model is that it does not appear to account for why the Mt Read Volcanics are located so precisely along the western margin of the Tyennan block (Corbett in Corbett and Turner, 1989, p.179).

The third class of models regarded the ultramafics as part of a single ophiolite sheet thrust over the autochthonous Precambrian continental crust of Tasmania, and later down-faulted to its present position (fig. 5, model 4; Berry and Crawford, 1988). In this model, based loosely on analogy with the end-Cretaceous emplacement of the Oman ophiolite sheet on to the Arabian shield, the whole of the western Tasmania terrane is regarded as a single continental block which was thrust, in the Middle Cambrian, beneath an oceanic island arc along an eastward-dipping subduction zone. Post-collisional extension is postulated to have formed grabens in which the Dundas Group accumulated, while at the same time the Mt Read Volcanics were erupted. Perceived difficulties with this model are the intercalation of low-Ti basalts, considered to be part of the allochthonous sheet, with the basal Dundas Group sediments, which contain quartzose detritus derived from the underlying autochthon, the lack of evidence in coeval sediments for detritus derived from the allochthonous sheet, and the lack of a reason for the apparent restriction of the Mt Read Volcanics to the western and northern margin of the Tyennian region.

A separate important problem is to determine whether the arcuate shape of the Dundas-Fossey structure, and thus by association, the Mt Read Volcanics, is a primary palaeogeographic feature or whether it has been produced by bending of an originally more linear trend. Corbett (in Corbett and Turner, 1989, p.168) suggested that the parallelism of trends in the Dundas-Fossey arc with lithological trends in the underlying Precambrian Tyennan block indicate strongly that the bend is a superimposed tectonic feature, possibly formed during the Devonian.

(b) Eastern Tasmania terrane

The contrast between the eastern and western Tasmania terranes could hardly be more marked. Whereas the western Tasmania terrane has a relatively long and complex late Precambrian (since ~800 Ma) and Early Palaeozoic history, involving a diversity of rock associations from continental-margin to deep-marine, arguably associated with slices of ocean floor and a calc-alkaline volcanic arc, the exposed eastern Tasmania terrane comprises simply deep-water turbidites into which mid-Palaeozoic granitoids were emplaced. The oldest rocks (480 Ma) could well be younger than the inferred mid-Cambrian emplacement of the ultramafic sheet in the western Tasmania terrane, and younger than the Mt Read Volcanics.

Most tectonic models for the eastern Tasmania terrane involve deposition of quartzose clastics in a submarine turbidite apron derived from cratonic sources to the south-west. The Tamar fracture system is seen as a zone of significant sinistral (Williams, 1978) or dextral (Baillie, 1985) displacement, and thus the source of the turbidite apron may not have been the western Tasmania terrane.

The junction between the two terranes lies along the line of the Tamar River, where there is an abrupt change in rock type as well as structural style and symmetry. The main NNW-trending folds in the eastern Tasmania terrane verge eastwards, whereas those in the adjacent western Tasmania terrane verge WSW. Some people (e.g. Williams, 1989, p.489) consider that there is a sedimentary linkage between the eastern and western terranes in the Early Devonian, but this was discounted by Powell and Baillie (1992) on re-examination of the outcrops. There is thus no proven linkage between the two terranes until the later phase of WSW-verging deformation in the Middle Devonian (Williams, 1989; Powell and Baillie, 1992).

An important, but not widely publicised feature of the eastern Tasmania terrane is the widespread presence of megakinks in the regional NNW-trending structure (Goscombe and Findlay, 1989). These megakinks, known in the mainland continuation of the Lachlan Fold Belt from the work of Powell *et al.* (1985), involve sharp swings in the strikes of steeply-dipping axial-plane cleavage through angles of 12° to 43°, with angles of 16° to 18° being most common. Goscombe and Findlay (1989) estimate that the megakinks represent a NNW-SSE crustal shortening of 3 to 8 per cent, with compensatory ENE-WSW crustal extension, and no crustal thickening. The megakinks postdate the first generation of folds and intrusion of the Middle to Upper

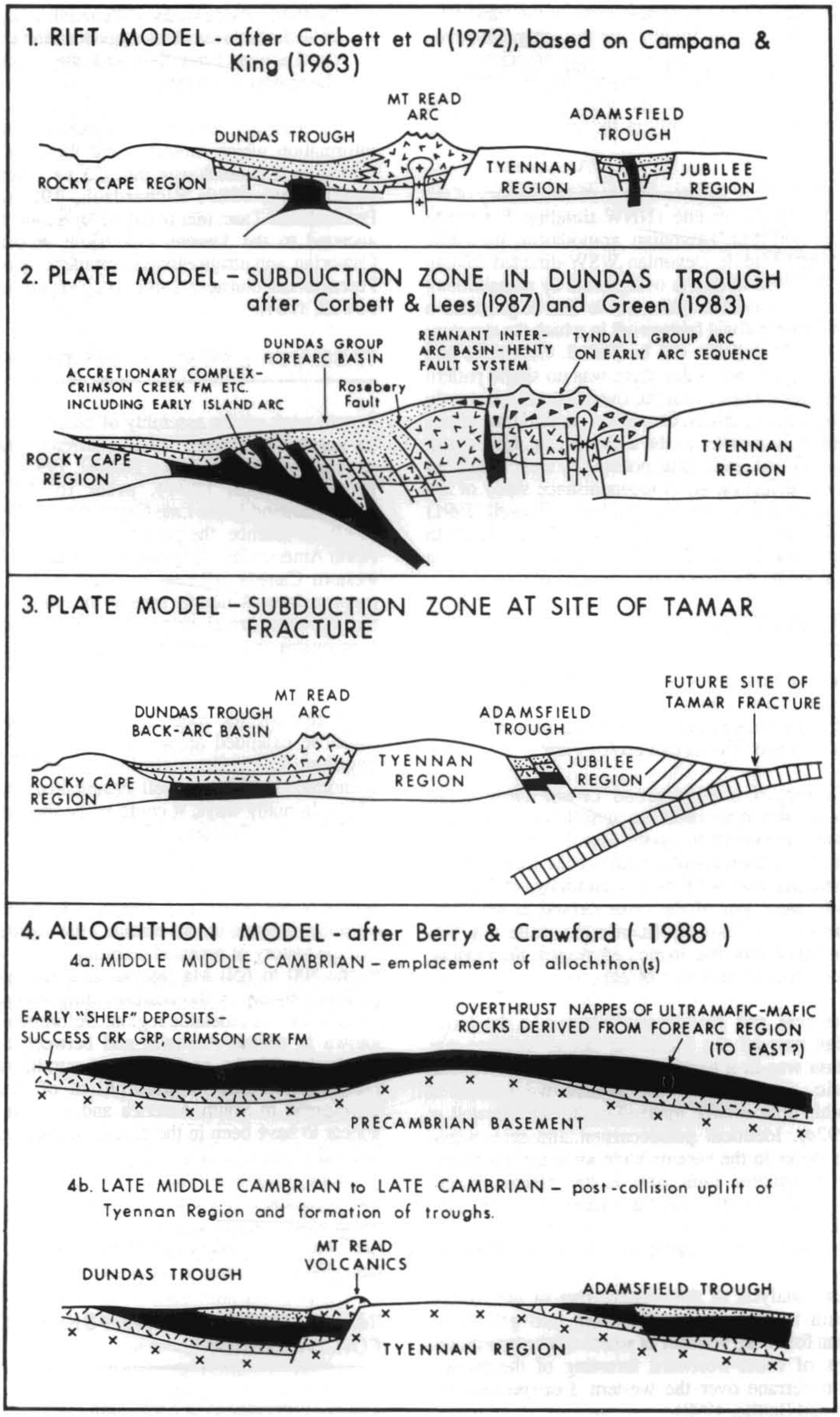

Figure 5

Schematic tectonic models for the western Tasmania terrane (from Corbett and Turner, 1989, p. 176).

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Devonian granodiorites, and appear to fit in the same time gap as the WSW-directed folding and thrusting. However, the kinks appear to postdate the S_2 cleavage associated with the WSW-directed thrusting (Powell and Baillie, 1992), and are thus probably formed in the waning stages of the thrusting, or afterward, possibly in the mid-Carboniferous (Powell, 1984*b*).

The importance of this 3-phase deformational history of the north-east Tasmania terrane (NNW-trending E-verging folding before Middle Devonian granodiorite intrusion, followed by late Middle Devonian WSW-directed folding and thrusting, which in turn is overprinted by megakinking which could be mid-Carboniferous) is that it provides a temporal and orientational framework in which the structure of individual gold deposits can be placed. Goscombe and Findlay (1989, p.19) noted that there was no single pattern to the gold-bearing veins, with the overall trend apparently not rotated by the megakinks. One of the common directions (032°) is precisely parallel to the sinistral megakink trend. They concluded that gold veins potentially were emplaced throughout the deformation. A reconnaisance study of the gold veins in the Lefroy-Beaconsfield area (Powell, 1991) suggested that the gold veins there could be related to WSW-directed folding and thrusting. Clearly, more work is required to evaluate the structural relations fully.

NEW INFORMATION

Recent structural and stratigraphic studies in Victoria and Tasmania have clarified relationships between some units, and opened up possible relationships with others. The most important of these for Tasmanian geology are:

1. Recognition of a widespread Lower Ordovician quartzose turbidite sheet in which palaeocurrent directions are consistently to the east or north-east. This apron extends throughout Lachlan Fold Belt, thereby demonstrating that both eastern and western Lachlan Fold Belt were part of the same terrane in the Early Ordovician. The eastern Tasmania terrane has this tectonostratigraphic unit in the Lefroy area (Stony Head Sandstone of Powell *et al.*, 1992*a*).

2. Palaeocurrent and provenance patterns in the Early Devonian part of the Mathinna Group indicate that deposition was in a basin elongate to the NNW, with cratonic sources to the south-west and a feldspathic/lithic source inferred to the east (Powell *et al.*, 1992*a*). Identical palaeocurrent and provenance patterns occur in the eastern Melbourne trough, where the Mt Wellington fault zone is the eastern margin (Powell *et al.*, 1992*b*). This connection across the Bass Strait ties the tectonic position of the eastern Tasmania terrane to the western Lachlan Fold Belt in the Devonian.

3. Structural analysis of the western part of the eastern Tasmania terrane shows there are two groups of Devonian folds, the younger of which can be interpreted in terms of south-westward thrusting of the eastern Tasmania terrane over the western Tasmania terrane (Powell and Baillie, 1992).

4. Recognition of the thrust-faulted nature of the contact between Precambrian rocks of the Badger Head block and Cambrian rocks of the Port Sorell region (Leaman *et al.* 1973; Elliot *et al.* 1992), and similar relationships in many other parts of Tasmania (Leaman 1986*a*, *b*; 1990) led Leaman *et al.* (1992) to postulate that most of the Precambrian rocks of Tasmania comprise a series of Palaeozoic thrust slices embedded in the western part of the Lachlan Fold Belt and the eastern part of the Kanmantoo Fold Belt.

These findings, taken in conjunction with published information which indicates that the crustal thickness in Tasmania is anomalously thin (23 to 27 km, Leaman and Richardson, 1989; Richardson, 1989), suggest that Precambrian Tasmania could be an exotic block or blocks accreted to the Tasman Fold Belt, probably during the Cambrian, and not an eastward promontory of the Australian Precambrian craton as previously depicted (Veevers and Powell, 1984).

TASMANIA'S POSITION IN GONDWANALAND

Recent work on the assembly of Gondwanaland has raised the possibility of some radically different palaeogeographic reconstructions (fig. 6; see Dalziel, 1991, 1992; Hoffman, 1991: Moores, 1991), prior to the assembly of Gondwanaland in the Late Cambrian (fig. 7; Li and Powell, 1992). In essence, the postulate is that the western part of North America lay alongside Australia and Antarctica, with western Canada adjacent to south-eastern Australia. My purpose here is not to review the merits of the various possible reconstructions, but to point out the importance such a reconstruction could have once the best fit has been determined.

First, metallogenic zones known to exist in one continent could be extended along strike into another continental fragment. Lineament control on the distribution of major economic deposits is well established (e.g. O'Driscoll, 1985). In many ways, it could be be the matching of such now-disjunct features which will fine-tune the most acceptable fit.

Secondly, the position of Tasmania in the pre-Gondwanan assembly is by no means certain. I have already pointed out that the history of repeated deformation and metamorphism in the 800 to 650 Ma interval is quite unlike the stable platform history of the nearest contiguous part of cratonic Australia in the Adelaide region. Deformation of this age is known in central Australia and between the Pilbara and Kimberley blocks of Western Australia (Myers, 1990). Deformation and metamorphism of this age is also widespread in South America and western Africa, which appear to have been in the process of amalgamation in this interval (Ramos, 1988). It is possible that either or both of the Rocky Cape and Tyennan regions could have come from the Argentine region during the early Cambrian breakup of the pre-Gondwanan supercontinent, and become welded to the Tasman Fold Belt during the Late Cambrian. Careful palaeomagnetic study is required to test this hypothesis.

IMPLICATIONS OF A THIN-SKINNED MODEL FOR TASMANIA

The full implications of a thin-skinned model for the crustal structure of Tasmania have yet to be worked through, but some preliminary comments can be made.

1. The stratigraphic order and/or tectonic zonation of economic deposits could be attenuated, duplicated or reversed, depending on the geometry of the thrust faults present.

9/11

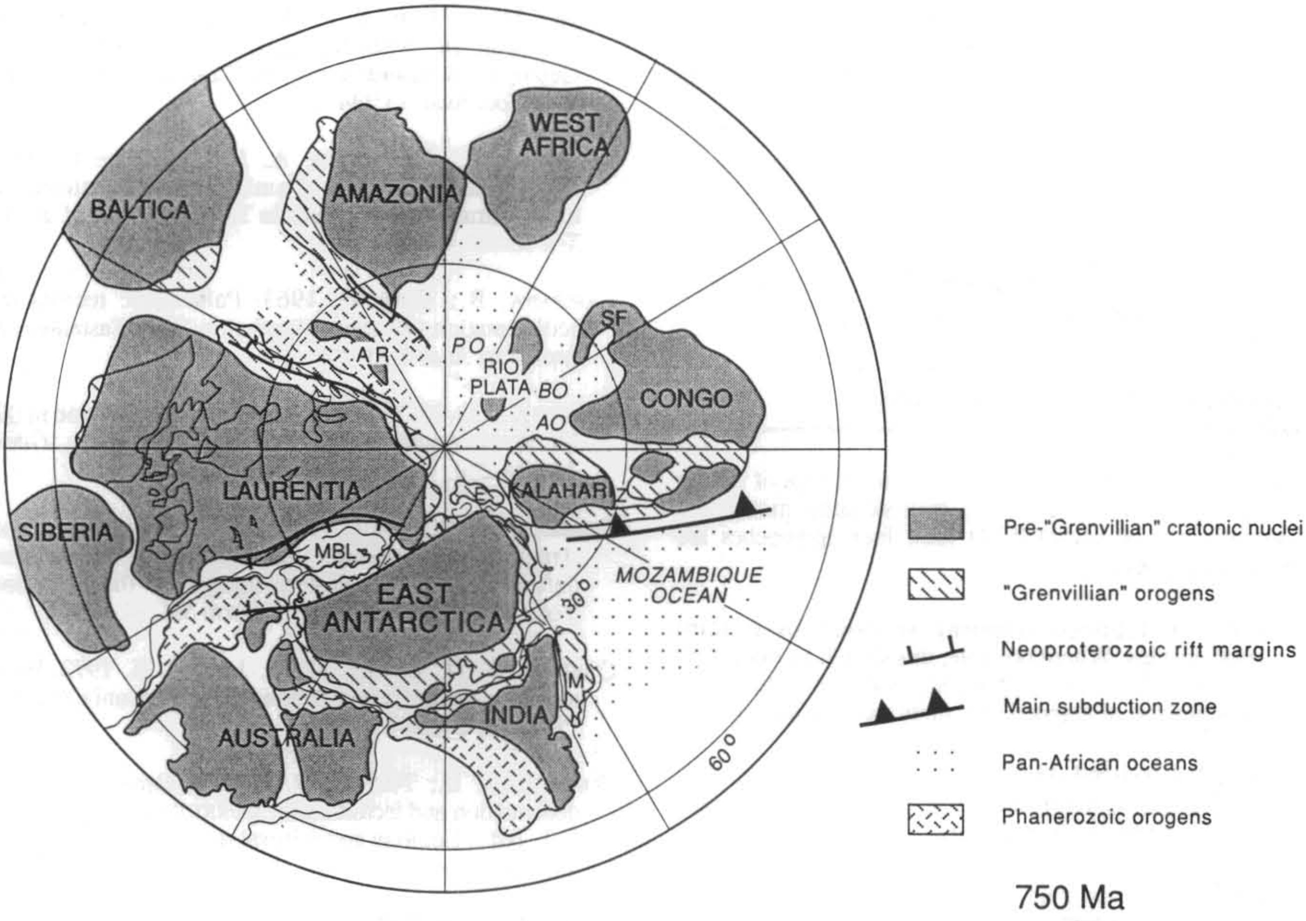

Figure 6

Late Precambrian supercontinent reconstruction from Dalziel (1991, 1992). Note Tasmania's position within the Neoproterozoic rift.

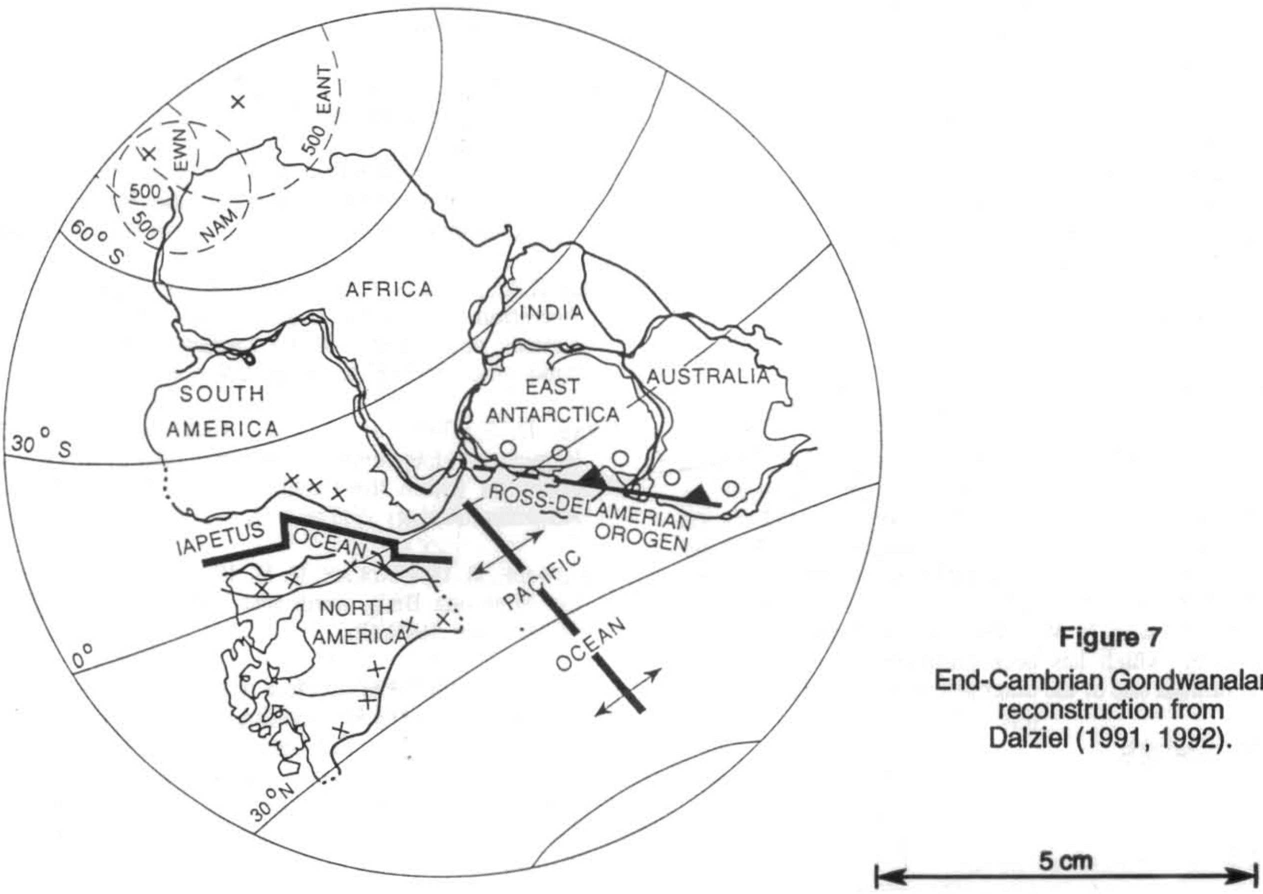

Figure 7

End-Cambrian Gondwanaland reconstruction from Dalziel (1991, 1992).

2. Exploration models based on assumptions about a normal stratigraphic order for the rock successions will need re-evaluation to determine if thrust repetitions could have occurred.

3. Exploration strategies based on rift models may have to be re-evaluated if the target host rocks are shown to be slices of a now-dismembered terrane.

4. It may be worth exploring beneath Precambrian slices if the right kinds of deposit and structural geometry present themselves.

WHERE DO WE GO FROM HERE?

Like all novel hypotheses, there needs to be a lot of testing of the framework before the thin-skinned model for Tasmania can be accepted. At least four approaches are worthy of support.

1. Further detailed mapping in areas of crucial relationships. Where possible, this should be done with full geophysical support so that the subsurface continuation of mapped structures can be constrained.

2. Selected diamond-drilling should be carried out in areas of potential economic interest to delineate the shapes of possible thrust-fault structures.

3. More palaeomagnetic studies should be carried out to determine when the Rocky Cape and Tyennan regions became welded to the Australian craton, and whether the arcuate shape of the Mt Read Volcanics is primary, or a result of later deformation.

4. There should be an integrated approach by Industry, Government and academic organisations to obtain funding for one or more deep seismic profiles across structures of major interest.

It is salutary to note in this regard the recent revolution in geological thought about classical fold belts such as the Appalachians of North America, which has come about in the last 10 years solely from the results of the COCORP seismic reflection profiles. The short deep-crustal profile in central Victoria (Gray *et al.*, 1991) raises possibilities that there could be wholesale mid-crustal detachment in the western Lachlan Fold Belt.

ACKNOWLEDGEMENTS

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