PERGAMON

Journal of Structural Geology 22 (2000) 529–535

JOURNAL OF STRUCTURAL GEOLOGY

www.elsevier.nl/locate/jstrugeo

Character and kinematics of faults within the turbidite-dominated Lachlan Orogen: implications for tectonic evolution of eastern Australia: Reply

David R. Gray[a,*], David A. Foster[b]

[a]*VIEPS Department of Earth Sciences, Monash University, Melbourne, Victoria 3168, Australia*
[b]*Department of Geology, University of Florida, PO Box 112120, Gainesville, FL 32611-2120, USA*

Received 19 October 1999; accepted 4 November 1999

1. Introduction

The Discussion of Taylor and Cayley really does not directly address the content of our paper (Gray and Foster, 1998), apart from reference to the Moyston Fault Zone and interpretation of the deep crustal seismic data with which we have actively been involved (see Gray et al., 1998; Barton et al., 1998; Korsch et al., 1999). We iterate that our paper sets out to describe the nature, geometry and kinematic significance of faults within a turbidite-dominated orogen. Taylor and Cayley have totally ignored this. They apparently have not understood the significance of the fabrics and overall geometry of the fault systems, although they dispute the overall deformation setting. Having had the opportunity to either work in or visit other orogenic belts (e.g. the Appalachians, the Canadian Rockies, the Sevier Orogen, the Reinisches Schierfergebirge, the French and Spanish Variscides, the Wopmay Orogen of northwest Canada, the Otago Schist belt of New Zealand, and the Damara orogen of Namibia), we maintain that turbidite-dominated orogens do have different overall styles of deformation (see table 1, Gray and Foster, 1998). Leading-imbricate fan geometry of the western and central Lachlan Orogen, involving tiered detachments, is a consequence of the former oceanic stratigraphy, whereas the deformation fabrics are a consequence of the deformation environment. The use of the term accretionary wedge thrust-belt (Gray and Foster, 1998, table 1) does not necessarily equate directly to subduction complexes, although in other papers we have linked underthrusting in the Lachlan Orogen to subduction scenarios (e.g. Foster et al., 1996, 1999; Gray and Foster, 1997; Gray et al., 1997). It is this subduction association for the western Lachlan Orogen that Taylor and Cayley object to.

Taylor and Cayley have a specific agenda that relates to the wider concerns of the tectonic evolution of eastern Australia. They are interested firstly in pushing a model of intra-plate collapse of a marginal sea driven by outboard convergence (Fig. 1a), and secondly applying discrete orogenic pulses that were formerly defined by both regional and local unconformities. This is the background to their discussion, and as such only indirectly relates to our paper that they claim to be discussing. Although Taylor and Cayley agree with our marginal sea setting (see Gray and Foster, 1997; Foster et al., 1999), they disagree with the nature of the substrate to the ocean basin and the mechanism to shorten and close the basin (see Cayley et al., 1999). As part of their critique they have taken the liberty to fit a regional tectonic interpretation onto our model figure (fig. 18, Gray and Foster, 1998), something that was clearly not our intent in this paper. Readers are referred to a recent paper (Foster and Gray, 1999) for a more complete treatment of the geometry, timing and propagation sequence of faults based on a palinspastic restoration for the western Lachlan Orogen (see Foster et al., 1999, fig. 9).

* Corresponding author.

PII: S0191-8141(99)00167-4

2. Discussion on intra-plate orogenesis

Taylor and Cayley (this Discussion) refer specifically to the western Lachlan Orogen, where they have undertaken mapping for the Victorian Geological Survey since 1991. The western Lachlan Orogen however, cannot be taken in isolation (see Gray, 1997; Foster et al., 1999), as Cayley and Taylor (1996, 1998a) and Taylor and Cayley (this Discussion) have conveniently done. It is part of a wider orogenic system, and within the envisaged intra-plate oceanic setting the deformation requirements and thermal history become extraordinarily complex (see Gray, 1997; Foster et al., 1999, fig. 8). The mechanics of the intra-plate model and how the orogenic pulses fit into a plate tectonic scenario have never been presented or discussed. In our opinion, there is a major problem in that the subduction zone driving deformation in the intra-plate model is at least 1500 and may be up to 2500 km from the western and central belts during the period from 500 to 400 Ma (see Fergusson and Coney, 1992a, fig. 11c; Foster et al., fig. 10b). Furthermore, the 'forearc' region, that is the intervening area between the 'magmatic arc' (Wagga Omeo Metamorphic Complex) and the subduction zone is still receiving sediment at this time and did not undergo deformation until 400 Ma through to 340–320 Ma (region 3, Fig. 1b). We find it very difficult to reconcile how stress, to cause significant shortening and final closure of a marginal ocean basin, can be transmitted across this region. In particular how stress is transferred across the hot, and therefore weakened, frontal 'arc', when the distance involved is some 1500 km (Fig. 1b). This convergence may only be possible due to an outer subduction system if the angle of subduction was extremely low for the full 2500 km.

3. Deformation mechanics of sediment wedges

The mechanics of various deformation scenarios for sediment wedges is important for the tectonic evolution of the western Lachlan Orogen. Deformation of significant accumulations of sediment on the sea floor can be modeled via different mechanisms; 'bulldozer' scenario with a push from the rear (Fig. 2a), the underthrust model (Fig. 2b), the 'subduction' model of Beaumont (Fig. 2c) and the 'vice' model (Fig. 2d).

For the western Lachlan Orogen the geometry of the folds and faults, and the propagation of the deformation front from west to east matches the models in Fig. 2(a–c). The 'push from the rear' or 'bulldozer' model (Fig. 2a) would require a push from the craton and is clearly not appropriate. The tectonics of the Gondwana margin at this time therefore requires some form of underthrusting (models 2b and 2c), which in an oceanic environment with involvement of oceanic crust we would argue is a form of 'subduction'. This is our model presented in fig. 18 of Gray and Foster (1998). In the Beaumont model the retro-shear is related to the definition of the singularity point (i.e. the point

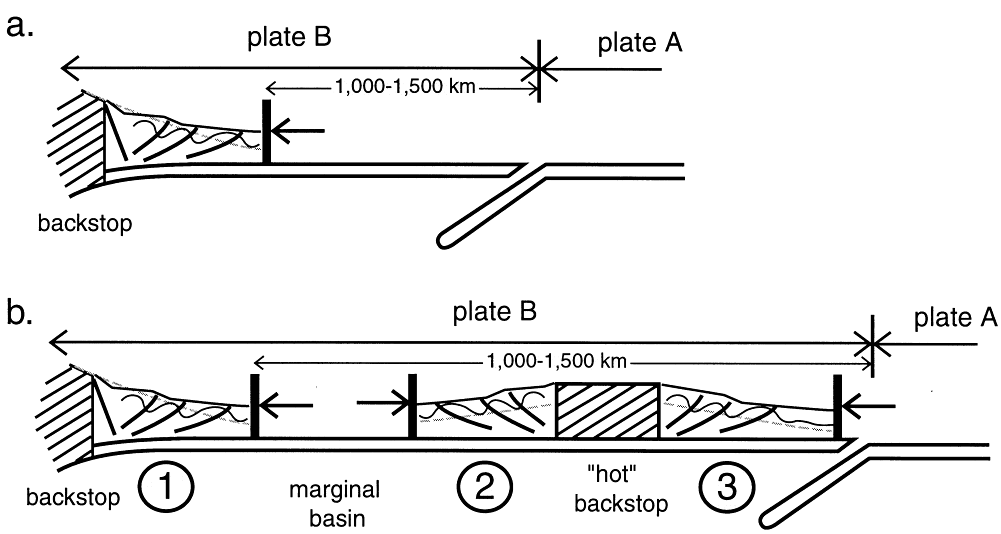

Fig. 1. Intra-plate deformation model in a marginal sea setting driven by outboard convergence. (a) Western Lachlan Orogen in terms of the Cayley and Taylor intra-plate model. The components include a backstop (thickened continental crust) and a Mariannas type subduction system between plates A and B, some 1000–1500 km from the deforming sediment prism (wedge). Problems relate to stress transfer across a distance of 1500 km and to the cause of internal deformation of the sediment wedge. Requirement of the Taylor and Cayley intra-plate deformation model is a push from the east (i.e. ocean-side). (b) Configuration of the Lachlan Orogen at 37.5°S showing three separate thrust systems 1, 2, and 3 each with different overall tectonic vergence (see Gray, 1997; Gray et al., 1997; Gray and Foster, 1998) within an intra-plate tectonic setting.

where the subducting slab dip steepens). The geometry of the western Lachlan Orogen matches this scenario with retro- and pro-shears forming as part of the wedge thickening to develop and maintain the critical wedge taper. In the context of the western Lachlan Orogen, this model clearly requires underthrusting towards the craton (i.e. to the west) and subduction beneath the wedge, initiated where the retro-shear (Moyston Fault) formerly intersected the Moho.

The nature of the backstop will clearly affect the geometry of structures within the deforming prism or sediment wedge (Byrne et al., 1993). Retro-shears (back-thrusts) will also develop depending on the interface angle between the backstop and the wedge (see Byrne et al., 1993, fig. 3). If the interface is inclined towards the wedge, then the sediments will be overthrust across the backstop (i.e. towards the craton), but once again this requires underthrusting of the sediment wedge from the east. Taylor and Cayley (this Discussion) argue that the simplest interpretation of western Lachlan evolution involves a push from the east, involving underthrusting and thickening of the entire crust. The nature of the underthrust material is alluded to be an older, rigid, continental crust beneath the Melbourne Zone (Fig. 3a). Recent geodynamical modelling however, appears inconsistent with the presence of continental crust beneath the western Lachlan Orogen (see O'Halloran and Rey, 1999). Buoyancy arguments suggest the western Lachlan Orogen is underlain by dense mafic crust (oceanic substrate).

The intraplate tectonic model (Fig. 1a) cannot equate with the 'vice' model for sediment wedge deformation (Fig. 2d). In this scenario deformation activates and propagates from both the backstop and the region in front of the moving piston (see Fig. 2d). This will produce upright folds and no 'tectonic' vergence, and is clearly inconsistent with the chronology of structural development for the western Lachlan Orogen and the well displayed vergence.

4. The western boundary fault—the Moyston Fault: backthrust or retro-shear?

The major western boundary fault (Moyston Fault) is an E-dipping high strain zone that has been defined and interpreted by Cayley (1995) and Cayley and Taylor (1996, 1998a) to represent the main décollement horizon for the western Lachlan Orogen. Because of metamorphic grade differences, they argue that this fault has the largest displacement of any fault in the western Lachlan. Cayley (1995) required this fault to be the leading or frontal fault, and as such all the other E-directed faults were back-thrusts. Most thrust-belts however, do not have this geometry. In general terms the dip direction of the dominant fault population within a thrust-belt defines the tectonic vergence direction, and therefore the overall transport direction of the thrust-belt 'wedge' as a whole.

In other interpretations (this Discussion) they suggest it is a long-lived retro-shear (after Beaumont et al., 1994) that requires underthrusting from the east toward the craton. In this scenario, the deforming sediment wedge can have displacement components both towards and *away* from the craton. Foster et al. (1999, fig. 10) have argued that the Moyston Fault Zone is a back-thrust activated between 420–410 Ma. The high strain zone of the Moyston Fault clearly truncates fabrics associated with the W-dipping thrust system in the hanging wall. The final overthrusting on the Moyston Fault outlived and is therefore younger than the older

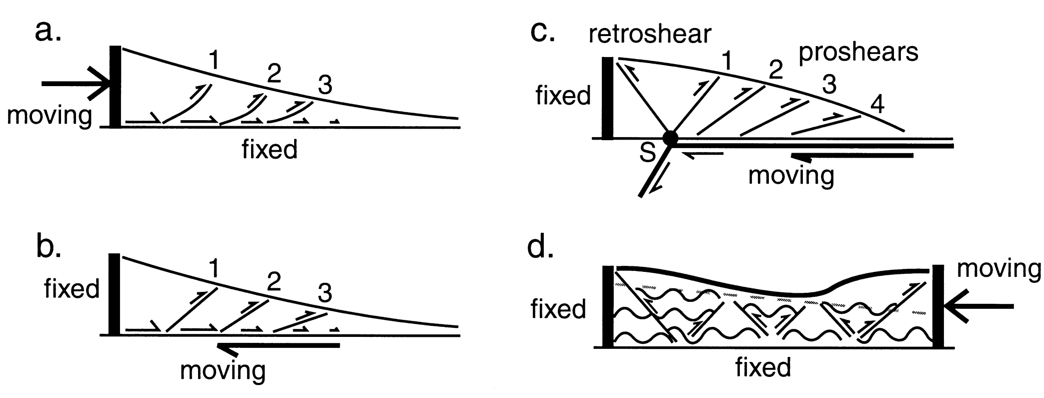

Fig. 2. Mechanics of sediment wedge deformation. (a) 'Bulldozer' scenario with a moving plate (piston) and a fixed base. (b) 'Underthrusting' scenario with a fixed plate (backstop) and a moving base. (c) Mantle 'subduction' scenario with fixed plate (backstop), moving base with a knick point (subduction zone) which is a singularity for stress and strain (after Beaumont et al., 1994). (d) 'Vice' scenario with a fixed plate (backstop) and a moving plate (piston = micro-continent/arc).

faults to the east (e.g. Heathcote Fault Zone). Unlike Taylor and Cayley (this Discussion) we do not believe that the Stawell–Ararat Fault Zone (see Gray and Foster, 1998, pp. 1697–1699, figs. 3, 5) is the easternmost part of the Moyston Fault high strain zone.

We accept that deformation in the western Lachlan Orogen is an example of a deformed sediment wedge with a significant retro-wedge deformation component (cf. Willett et al., 1993, fig. 4a). We do not accept as a corollary that the "large craton-directed Moyston Fault is one element reminiscent of those associated with the classic orogenic systems of North America, involving thrust-imbrication of passive margin sequences towards a cratonic interior". One fault clearly does not make the Lachlan Orogen like the so-called classic North American orogens (see Fig. 3). The overall geometries, complex transport directions, timing of deformation and thermal histories are different (see Gray, 1997; Van der Pluijm and Marshak, 1997, chapter 19).

We agree that there are structural and metamorphic similarities of the western Lachlan Orogen with the Taiwan Slate Belt. Taylor and Cayley point out that in Taiwan overthrusting of slate and sandstone sequences towards the Chinese craton is due to collision of the Luzon magmatic arc. This is certainly not the situation for the western part of the Lachlan Orogen where underthrusting towards the craton causes thickening and accretion of a sediment wedge onto the margin. This event(s) certainly does not involve continent-arc collision (i.e. a push from the rear or east).

5. Diagnostic characteristics of accretionary wedges: broken formation?

Taylor and Cayley question lack of similarities with known fans, arguing that a general lack of broken formation indicates that the deformation of the western LFB cannot be considered an accretionary wedge (sediment prism). Questions still remain as to how the age and thickness of an existing fan can affect how it deforms. Young unconsolidated materials with trapped pore water caught up in a trench less than 5 Ma after deposition, should certainly be dominated by broken formation. Older fans with thicknesses in excess of 5 km should contain consolidated sediment and deform largely via chevron folding (see Knipe and Needham, 1986, fig. 5), particularly if the sediment sat on the ocean floor for some 20–30 Ma before deformation in a trench. Pre-existing fans with partially consolidated sediment should show chevron folding

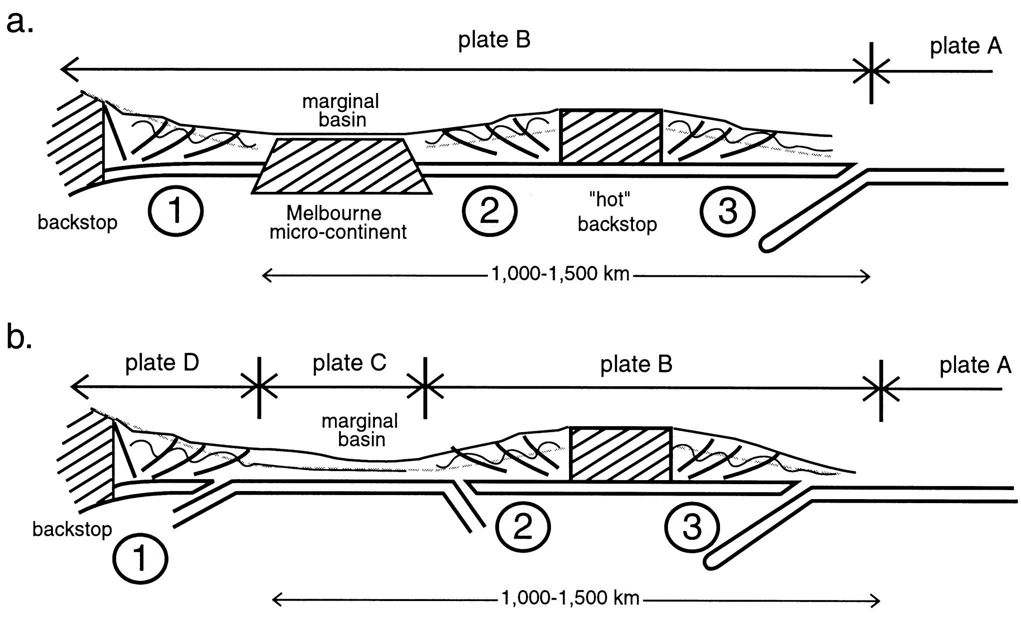

Fig. 3. Tectonic evolutionary scenarios for the southern Lachlan Orogen at 37.5°S latitude. (a) Cayley and Taylor (1999) model involving a rigid continental block beneath the Melbourne 'trough' or marginal basin. How the intervening ocean(s) closes with respect to the micro-continent and the 'hot' backstop (the high-*T* Wagga–Omeo Metamorphic Complex) with deformation of the attendant wedges 1, 2 and 3 is a problem. Buoyancy arguments (O'Halloran and Rey, 1999) suggest the western Lachlan Orogen is underlain by dense mafic crust (oceanic substrate). (b) Multiple subduction zone model after Foster et al. (1996, fig. 14) and Gray and Foster (1997, fig. 12) incorporating oceanic underthrusting (i.e. subduction) to facilitate crustal thickening and closure of the marginal sea. Thrust-belts 1, 2 and 3 are accretionary wedge types after Gray and Foster (1998, table 1) and involve deformation of sediment wedges due to underthrusting (see Fig. 2b).

cut by melange zones. We argue that sediment wedges deformed on the sea floor will therefore show varying deformation character, and may contain broken formation, chevron-folding and/or faulted, imbricated slabs. As such, broken formation is not necessarily a requisite for defining a subduction–accretion wedge. Disrupted units containing sea-floor volcanics and chert, with minor limestone do exist along some of the major fault zones (see Spaggiari et al., 1998, b); in particular the Heathcote and Governor Fault Zones (see fig. 2, Gray and Foster, 1998).

The major part of the western Lachlan Orogen sediment was part of a Bengal-type fan (see Fergusson and Coney, 1992b), which sat on the sea floor some 50 Ma before deformation. This is why chevron folding dominates and why there is little evidence of broken formation. The melanges and broken formation that typify 'offscraping' in the frontal, shallow levels will therefore not be present. Furthermore some 10 km have been stripped off central Victoria since deformation and structural thickening (Offler et al., 1998). This means we are looking at the deeper levels within the deformed sediment wedge. We argue that the amount of erosion will also affect what is preserved, whether the upper levels (offscraped region) or deeper levels (underplated region) of the accretionary wedge. The intervening marginal sea (Melbourne trough) is quite different to the other structural zones, because Ar–Ar geochronology shows that sediment within this zone was derived from the Stawell and Bendigo–Ballarat Zones to the west. Parts of this belt do show evidence for soft sediment deformation, with slump zones, broken formation (mélange) along major faults and mud injection structures (see Gray et al., 1999).

Metamorphic studies by Offler et al. (1998) indicate intermediate pressure metamorphism of the western Lachlan Orogen turbidites and a low geothermal gradient in agreement with subduction-related oceanic settings proposed by us. Moreover, the presence of transitional blueschist facies blocks in the metavolcanic belts that are bounded by the major faults are also consistent with an underthrusting situation. These are Franciscan-like blueschist knockers in both scaly-mudstone matrix and serpentinite matrix mélange, typical of type B blueschists which occur in oceanic settings involving subduction (see Maruyama et al., 1996). Taylor and Cayley question the timing of blueschist metamorphism, but the available geochronological evidence for the low-T metamorphosed Cambrian metaigneous rocks suggests that the low-T, high-P metamorphism occurred at ~455 Ma, the same age as the metamorphism in the sediments (Foster et al., 1999; Spaggiari et al., 1999).

6. Lack of a volcanic arc

The lack of a late Ordovician volcanic arc is hardly an argument against subduction and underthrusting to deform the basin. The best geochronological and stratigraphic evidence suggests that deformation in the turbidite sequence began about 455 ± 5 Ma, and that by ~440 Ma a significant part of the western half of the western Lachlan Orogen had been shortened by > 50%. This would suggest that 'underthrusting' and shortening began around 450 Ma. If the marginal basin was initially ~1000 km wide, shortening of part of the basin by 50–70% would give only 250–300 km of subduction at the most. We have consistently argued that not all of the oceanic crust was subducted, but that a significant part of the upper oceanic crust was peeled off and imbricated forming the present mafic lower crust. Nevertheless, these maximum values of subducted marginal basin crust are in the range 250–300 km by 440 Ma. At an angle of say 30° the frontal or deepest part of the slab would not reach depths more than 125–150 km, which is insufficient for major melt generation. It took another 40 Ma before the next 200 km or so of material was subducted, and based on the geochronologic and stratigraphic evidence most of this later shortening took place between about 400 and 385 Ma (Foster et al., 1999). Only at that point in time would enough oceanic crust have subducted to generate melting and produce the voluminous, metaluminous plutons in the western part of the western Lachlan Orogen.

We would therefore argue that the lack of preserved arc magmatism is consistent with our model and in fact predicted by our model, and that timing of the onset of magmatism at about 410–400 Ma (Foster et al., 1999) is also consistent. Furthermore, the lack of magmatism between 450 and 420 Ma should not be considered as evidence for or against subduction or underthrusting to close the basin. The age of the oceanic crust was probably no more than ~50 million years old and the metamorphic P–T data suggest a slightly elevated geotherm for an oceanic environment. These factors could lead to very shallow-angle subduction and no melting. Moreover, in some situations where the subduction rate is very slow (as it would have been in the western Lachlan Orogen) the slab actually dehydrates at shallow depths and is not able to facilitate partial melting at deeper levels and never produces arc magmatism.

7. Episodic versus continuous deformation

Our Ar–Ar data set (see Foster et al., 1999) has been misinterpreted by Taylor and Cayley (this Discussion) and Cayley and Taylor (1998b). Unfortunately, they have extracted text out of context as well as misquoting us. They state that we have changed our earlier opinions presented in Gray et al. (1997) and Gray and Foster (1997), about continuous versus episodic deformations. We plainly state that we have not, and that we have always attempted to interpret the Ar–Ar data for the western Lachlan Orogen in terms of deformation of a wedge. Readers are referred to Foster et al. (1999, pp. 468–477) for the more detailed discussion, rather than extracts out of context supplied by Taylor and Cayley (this Discussion).

Rocks in a thrust environment clearly deform over a protracted period. They certainly do not deform uniformly everywhere through the deforming rock volume at any instantaneous point in time. The concept of progressive deformation for the western Lachlan Orogen was first proposed by Gray and Willman (1991a, b). From a structural point of view this is obvious and has been supported by studies in other orogens (e.g. Weber, 1981, p. 155: Rheinsiches Schiefergebirge). Taylor and Cayley want deformation to occur within the current orogenic framework with pulses (orogenic episodes) at 440, 420 and 400 Ma. We have argued that the data are better explained with progressive deformation in a wedge. The 'appearance of groupings' in the Ar–Ar data reflects movement along, and splaying from the basal décollement (see Foster et al., 1999, fig. 10). Fault movements will be episodic due to lock-up and stress release from slip (stick-slip behavior), and this will be manifest in the growth of micas during accumulated strain in the basal zones, as well as mica growth during cleavage development in the folded wedge above the basal décollement. The relationships between these two mica growth environments can be complex.

The grouping of Ar–Ar dates may well be due to changes in convergence rates, extensional episodes, or transpressional periods when the orogenic stress changed, but all of this seems to have occurred within the context of closing the marginal ocean. In actuality, Foster et al. (1999) found that even within the western part of the western Lachlan Orogen there was clear evidence within individual thrust sheets that the deformation process from folding to fold lock-up to thrusting took up to 15 Ma. When early bedding-parallel fabrics or bedding-parallel quartz veins are dated they give dates of ~455 Ma. Whereas, fabrics associated with the high strain zones and thrusts, and quartz veins along steep, late faults give ages ~440 Ma in all cases where we have been able to clearly separate the fabrics.

8. Conclusions

We maintain that the geometry and character of fault zones in turbidite-dominated orogens are distinct from fault zones in other types of orogens. Thrust systems in the Lachlan Orogen have leading-imbricate fan geometry involving tiered detachments, and require duplexing of the upper part of the oceanic crustal substrate. Major interzone faults contain remnants of pillowed, mafic volcanics, as well as blueschist blocks in both serpentinite matrix and scaly mudstone matrix-melange. The age of the blueschist metamorphism remains partly unresolved at this juncture, but present data suggests it is ~450–460 Ma. Analysis of wrench components along faults (Gray and Foster, 1998, p. 1715) gave movements less than 50 km, suggesting that there are no large displacement wrench or strike slip fault zones within the Lachlan Orogen.

The Discussion by Taylor and Cayley has misrepresented what we have said in Foster et al. (1999) about the nature and timing of deformation as inferred from Ar–Ar data. Dates from well-cleaved slates *and* from syntectonic quartz veins in the major fault zones of the western Lachlan Orogen clearly show an E-younging deformation sequence. Despite this, Taylor and Cayley (this Discussion) maintain that the geometry, complex transport directions and timing of deformation in the Lachlan Orogen support their model involving intraplate collapse of a marginal sea. They want deformation by 'outboard process'. We disagree. A simple statement without explanation (this Discussion) does not prove anything, particularly when utilizing 'pulses' of the old orogenic framework, which they have not linked into their model (see further discussion in Gray et al., 1997; Gray and Foster, 1997). They have argued that there is no evidence diagnostic of subduction–accretion processes. What actually happens in a subduction complex is dictated by the state of consolidation and the pore pressure within the sediment. Taylor and Cayley have assumed like many others (e.g. O'Halloran and Bryan, 1998) that the 'textbook' subduction zone must consist of broken formation and have a volcanic arc, and therefore forearc volcanilithic sediments as input into the trench or forearc region. Conceptually it is much simpler to imagine a marginal ocean basin closing by underthrusting and subduction rather than just thickening. Regardless of terminology, we maintain that the evidence for underthrusting is strong and that underthrusting in an ocean environment is an evident form of subduction.

References

Barton, T.J., Gray, D.R., Owen, A.J., Korsch, R.J., Drummond, B.D., Foster, D.A., 1998. Crustal structure in the western Lachlan orogen, based on a seismic transect to the north of the Grampians. In: Finlayson, D.M., Jones, L.E.A. (Eds.), Mineral systems and the crust–upper mantle of southeast Australia, Australian Geological Survey Organisation Record 1998/2, pp. 1–5.

Byrne, D.E., Wang, W.H., Davis, D.M., 1993. Mechanical role of backstops in the development of forearcs. Tectonics 12, 123–144.

Cayley, R.A., 1995. Recent advances in understanding the structural evolution of western Victoria. Geological Survey of Victoria Symposium Abstracts, Geological Survey of Victoria (unpubl.).

Cayley, R.A., Taylor, D.H., 1996. Geological evolution and economic potential of the Grampians area, Victoria. In: Recent developments in Victorian geology and mineralisation, Australian Institute of Geoscientists Bulletin 20, 11–18.

Cayley, R.A., Taylor, D.H., 1998a. The structural framework and tectonic evolution of the western Lachlan Fold Belt, Victoria. In: Finlayson, D.M., Jones, L.E.A. (Eds.), Mineral systems and the crust-upper mantle of southeast Australia, Australian Geological Survey Organisation Record 1998/2, pp. 29–33.

Cayley, R.A., Taylor, D.H., 1998b. Double divergent subduction: Tectonic and petrologic consequences: Comment. Geology 28, 1052.

Cayley, R.A., Taylor, D.H., VandenBerg, A.H.M., Moore, D.H., 1999. Proterozoic rocks in central Victoria and their tectonic implications. Geological Society of Australia Abstracts 53, 27.

Fergusson, C.L., Coney, P.J., 1992a. Convergence and intraplate deformation in the Lachlan Fold Belt of southeastern Australia. Tectonophysics 214, 417–439.

Fergusson, C.L., Coney, P.J., 1992b. Implications of a Bengal fan-type deposit in the Palaeozoic Lachlan Fold Belt of southeastern Australia. Geology 20, 1047–1049.

Foster, D.A., Gray, D.R., Offler, R., 1996. The western subprovince of the Lachlan Fold Belt, Victoria: structural style, geochronology, metamorphism, and tectonics. Geological Society of Australia, Specialist Group in Geochemistry, Mineralogy, and Petrology Field Guide 1, 89 pp.

Foster, D.A., Gray, D.R., Bucher, M., 1999. Chronology of deformation within the turbidite-dominated Lachlan orogen: Implications for the tectonic evolution of eastern Australia and Gondwana. Tectonics 18, 452–485.

Gray, D.R., 1997. Tectonics of the southeastern Australian Lachlan Fold Belt: structural and thermal aspects. In: Burg, J.P., Ford, M. (Eds.), Orogeny Through Time, Geological Society of London Special Publication 121, pp. 149–177.

Gray, D.R., Foster, D.A., 1997. Orogenic concepts—application and definition: Lachlan Fold Belt, eastern Australia. American Journal of Science 297, 859–891.

Gray, D.R., Foster, D.A., 1998. Character and kinematics of faults within the turbidite-dominated Lachlan Orogen: implications for the tectonic evolution of eastern Australia. Journal of Structural Geology 20, 1691–1720.

Gray, D.R., Willman, C.E., 1991a. Deformation in the Ballarat Slate belt, central Victoria and implications for the crustal structure across southeastern Australia. Australian Journal of Earth Sciences 38, 171–201.

Gray, D.R., Willman, C.E., 1991b. Thrust-related strain gradients and thrusting mechanisms in a chevron-folded sequence, southeastern Australia. Journal of Structural Geology 13, 691–710.

Gray, D.R., Foster, D.A., Bucher, M., 1997. Recognition and definition of orogenic events in the Lachlan Fold Belt. Australian Journal of Earth Sciences 44, 1–13.

Gray, D.R., Janssen, C., Vapnik, Y., 1999. Deformation character and fluid flow across a wrench fault within a Palaeozoic accretionary wedge: Waratah Fault Zone, southeastern Australia. Journal of Structural Geology 21, 191–214.

Gray, D.R., Foster, D.A., Barton, T.J., Owen, A., Drummond, B., 1998. Results and implications of deep crustal seismic imaging in the western Lachlan Fold Belt, eastern Australia: SGSG and SGTSG Conference on Geological Structures and their Geophysical Signatures, Marysville, Victoria (December 1997), pp. 27–28.

Knipe, R.J., Needham, D.T., 1986. Deformation processes in accretionary wedges—examples from the SW margin of the Southern Uplands, Scotland. In: Coward, M.P., Ries, A.C. (Eds.), Collision Tectonics, Geological Society of London Special Publication No. 19, pp. 51–66.

Korsch, R., Barton, T., Gray, D.R., Owen, A.J., Foster, D.A., 1999. Structural interpretation of a deep seismic reflection transect in the vicinity of the Grampians, Victoria. Geological Society of Australia Abstracts 53, 139–141.

Maruyama, S., Liou, J.G., Terabayashi, M., 1996. Blueschists and eclogites of the world and their exhumation. International Geology Review 38, 485–594.

Offler, R., McKnight, S., Morand, V., 1998. Tectonothermal history of the western Lachlan Fold Belt, Australia: insights from white mica studies. Journal of Metamorphic Geology 16, 531–540.

O'Halloran, G.J., Bryan, S.E., 1998. Double divergent subduction: Tectonic and petrologic consequences: Comment. Geology 28, 1051.

O'Halloran, G.J., Rey, P.E., 1999. Isostatic constraints on the central Victorian lower crust: implications for the tectonic evolution of the Lachlan Fold Belt. Australian Journal of Earth Sciences 46, 633–639.

Spaggiari, C.V., Gray, D.R., Foster, D.A., 1998a. Tectonic significance of oceanic crustal slices and intermediate P metamorphism in the western Lachlan Fold Belt, Victoria. Geological Society of Australia Abstracts 49, 420.

Spaggiari, C.V., Gray, D.R., Foster, D.A., 1998b. Intermediate P metamorphism in Cambrian oceanic sequences, western Lachlan Fold Belt and implications for tectonics. In: Mineral systems and the crust–upper mantle of southeast Australia. Australian Geological Survey Organisation Record 1998/2, pp. 166–167.

Spaggiari, C.V., Gray, D.R., Foster, D.A., 1999. Occurrences and significance of Franciscan-like melange and blueschist metamorphism in Lachlan Orogen fault zones. Geological Society of Australia Abstracts 53, 248–249.

Weber, K., 1981. The structural development of the Rheinsiches Schiefergebirge. In: Zwart, H.J., Dornsiepen, U.F. (Eds.), The Variscan Orogen in Europe, Geologie en Mijnbouw, Vol. 60, pp. 149–159.

Van der Pluijm, B.A., Marshak, S., 1997. Earth Structure: An Introduction Structural Geology and Tectonics. McGraw Hill, New York 495 pp.

Willett, S., Beaumont, C., Fullsack, P., 1993. Mechanical model for the tectonics of doubly vergent compressional orogens. Geology 21, 371–374.