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Abstract

In regard to the tectonic history of the Lachlan Fold Belt, Aitchison and Buckman (2012) argued that "numerous aspects of the observed geology appear to be incompatible with the existing model" and that an "alternative model envisages arc-continent collision events (quantum tectonics) as a primary means of large-scale continental growth". My purpose is to challenge these arguments and to question their interpretation that rapid continental growth in the Lachlan Fold Belt has been achieved by thrusting of an island arc over a passive margin.

Keywords

paleozoic, processes, growth, continental, into, insights, tectonics, quantum, vs, accordion, comment, 22, issue, 2, september, 2012, pages, 674, 680, volume, research, buckman, solomon, aitchison, c, jonathan, gondwana, eastern

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1. Introduction

In regard to the tectonic history of the Lachlan Fold Belt, Aitchison and Buckman (2012) argued that “numerous aspects of the observed geology appear to be incompatible with the existing model” and that an “alternative model envisages arc-continent collision events (quantum tectonics) as a primary means of large-scale continental growth”. My purpose is to challenge these arguments and to question their interpretation that rapid continental growth in the Lachlan Fold Belt has been achieved by thrusting of an island arc over a passive margin.

2. One existing model of the Lachlan Fold Belt?

The Lachlan Fold Belt is an intriguing orogenic belt because it has formed by cryptic processes involving rapid continental growth along the early to middle Paleozoic margin of east Gondwana. Suggestions include development as an extensional accretionary orogen (Collins, 2002), rapid growth by formation of several subduction zones with accretion of widespread Ordovician remnant ocean basin deposits (Gray, 1997; Foster and Gray, 2000; Fergusson, 2003, 2009; Gray and Foster, 2004), and by strike-slip assembly of several Gondwana margin terranes (Glen et al., 2009). Thus it is clear that no consensus exists in relation to any particular model for its tectonic development. Coney (1992,

p. 6) pointed out that many proposals had been given “ranging through almost every possible plate tectonic setting imaginable to sentiments often expressed informally implying that the belt has nothing to do with plate tectonics”. No single model has wide acceptance contrary to the impression given by Aitchison and Buckman (2012, p. 674, and their figure 3).

3. Can the Ordovician Macquarie arc be interpreted as an allochthonous island arc?

It is widely accepted that the Lachlan Fold Belt is enigmatic. One issue is the nature of the relationship between the adjoining Ordovician quartz turbidites (continental margin successions) and the Macquarie arc. As noted in Aitchison and Buckman (2012), the Macquarie arc is characterised by volcanic rocks with an island arc geochemistry and associated with volcanogenic sandstones whereas the Ordovician quartz turbidites are quartz-rich and lack any evidence of clastic input from the island arc. These relationships are problematic as the Ordovician quartz turbidites are widely exposed west, south, east and even in between different belts of the island arc (Fig. 1). It is therefore not surprising that it has been interpreted as an overthrust slice. However, the present map geometry indicates a minimum 300 km westward displacement of the Macquarie arc over the Ordovician turbidites if it were an overthrust sheet.

The western belt of the Macquarie arc is associated with a significant magnetic anomaly (Glen et al., 2007). This magnetic anomaly is associated with a broad gravity high in the gravity map of Australia (see extract in Fig. 2). A more detailed description and interpretation of these anomalies is given in Glen et al. (2007). The wider gravity high has been interpreted as associated with mafic rocks deeply buried in the subsurface, and overthrust by Ordovician quartz turbidites. Support for this interpretation is observed in an east-west deep seismic line (Glen et al., 2002, 2007). A deep root to the Macquarie arc is also indicated by the Boggy Plains supersuite granites (Fig. 2) which have distinctive chemical characteristics thought related to melting of an underplated layer associated with the Macquarie arc (Wyborn et al., 1987). The geophysical data and granite geochemistry are consistent with the Macquarie arc being developed throughout the crust and unlikely to be a shallow thrust sheet as interpreted by Aitchison and Buckman (2012).

4. Analogous systems such as Taiwan and Oman?

Aitchison and Buckman (2012) cited what they regarded as several analogous situations to the Macquarie arc such as Oman and Taiwan. They give few details on this and it is hard to relate these settings to the Lachlan Fold Belt given the variation between them. A Taiwan analogy is inappropriate as in Taiwan the accreted island arc has acted as a bulldozer adjacent to the former passive margin and developed a fold-thrust belt with uplift of metamorphic rocks derived from below the passive margin succession. The Luzon arc in Taiwan has thrust over the margin to nowhere near the extent proposed for the Macquarie arc.

Oman on the other hand involves overthrusting of an island arc over a sediment-poor passive margin as emphasised by Meffre et al. (2000). The Lachlan Fold Belt is typified by abundant continental margin turbidites and it can hardly be considered a sediment-poor passive margin. As well, the Semail thrust sheet has widespread mantle and lower crustal sections with a basal metamorphic sole overlying highly deformed continental rise sedimentary rocks of the Hawasina thrust sheets and the carbonate platform (Searle and Cox, 1999). These features are lacking from the Macquarie arc.

5. Ordovician passive margin?

The idea that the Ordovician turbidites are part of a passive margin was suggested by VandenBerg and Stewart (1992) and has been raised by Aitchison and Buckman (2012). This part of their model is not explained, but it is apparent from their figure 3 that the passive margin has formed after the Delamerian Orogeny with the Ordovician turbidites partly overlying extended continental crust and oceanic crust. In western Victoria, basalts at the base of the Ordovician turbidite succession have a backarc basin geochemical affinity whereas in central Victoria the Cambrian volcanic successions underlying the Ordovician turbidites have boninitic and tholeiitic geochemical affinities consistent with an intraoceanic arc and backarc basement (Crawford et al., 2003). Thus a tectonic setting somewhat more complex than a passive margin is required to account for the widespread distribution of boninitic rocks underlying the Ordovician turbidites.

6. Comparisons with well-studied subduction complexes?

The idea of subduction complexes in the Lachlan Fold belt has been widely debated in the literature including discussion of sandstone compositions, structural characteristics and overall stratigraphy (see Gray and Foster, 2004). It should be obvious from the subduction complex models given for the Lachlan Fold Belt that the Ordovician turbidites are not interpreted as a trench wedge (cf. Aitchison and Buckman 2012). The Ordovician turbidites are recognised as a deformed turbidite fan deposited in an ocean adjacent to the Gondwana margin. In the undeformed state the Ordovician turbidites covered a huge area, comparable to the extent of the largest modern submarine fans such as the Bengal Fan (Fergusson and Coney, 1991) and clearly incompatible with deposition in a narrow trench. A recent crustal restoration for the Ordovician turbidite succession in western and central Victoria alone, found an original width of 1150 km (Gray et al., 2006) for just part of this huge submarine turbidite fan.

Sandstone compositions of the Ordovician turbidites as noted by Aitchison and Buckman (2012) are quartz-rich and are not derived from the Macquarie arc. Sandstones deposited as part of a trench-wedge may well be expected to show significant derivation from a magmatic arc. In the case of the Ordovician turbidites, the succession has been deposited into an ocean bordering east Gondwana, and part of this ocean has subsequently been subducted at several subduction zones according to the model of Gray and Foster (2004). Thus the sandstone compositions reflect the source of the turbidite succession (i.e. the Gondwana continent) and not its subsequent subduction accretion. Two modern subduction complexes that are also mineralogically mature and dominated by quartz are Nias Island (Indonesia) and Barbados (West Indies, Velbel, 1985). In both these modern examples, accretion of quartzose sandstones has occurred because submarine fans are located on the subducting plate. A similar but more complex scenario has been argued for the Lachlan Fold Belt (Fergusson, 2009).

7. A new alternative model?

Aitchison and Buckman (2012) claimed to give a new alternative model in which the Macquarie arc is overthrust to the west over an Ordovician passive margin. Fergusson and VandenBerg (1990,

p. 577-578) noted that “the contact between the island arc and the quartz-rich turbidite succession of the apparently adjoining basins is not a facies interdigitation as would be expected in this setting....”, and that “the contact has a geometry consistent with a major overthrust with the island arc succession (defined herein as the Parkes Terrane) in the hangingwall block and the continental margin turbidite wedge (Benambra Terrane) in the footwall”. This geometry has much in common with that proposed by Aitchison and Buckman (2012). However, it is clear from more recent work (e.g. Fergusson, 2003, 2009) that I have abandoned this hypothesis mainly because of the lack of evidence that the Macquarie arc has been thrust as much as 300 km westwards to its present location.

I agree with Aitchison and Buckman (2012) that the Macquarie arc was associated with an east-dipping subduction zone along its western side. It has been argued since the 1990's that subduction was not just restricted to the eastern margin of the Lachlan Fold Belt but developed two major fold-thrust belts in the Late Ordovician to Early Silurian in western Victoria (Stawell and Bendigo zones) and eastern Victoria (Tabberabbera Zone, Fig. 1) (Gray, 1997; Foster and Gray, 2000). I have argued that the subduction complex in the Tabberabbera Zone was part of a much larger fold-thrust belt (subduction complex) developed west of the Macquarie arc in a rapid phase of accretion (Fergusson, 2003). This was followed by westward migration of the magmatic arc with widespread melting of accreted Ordovician turbidites resulting in formation of abundant S-type granites and volcanic rocks of the Wagga-Omeo Zone in addition to now eroded arc volcanoes as shown by exposure of Alaskan-type ultramafic-mafic plutonic complexes in central New South Wales (Fergusson, 2003, 2009; Fergusson et al., 2005) (Fig. 1).

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Figures

Fig. 1. Map of the Lachlan Fold Belt in southeastern Australia (excluding Tasmania) showing the main structural zones and main outcrop extent of the Macquarie arc and the Ordovician quartz turbidites. Mélanges occur in the Narooma Zone, especially at Batemans Bay and Narooma (highlighted), and in the Tabberabbera Zone. The Thomson Fold Belt, Hay-Booligal Zone and northern extensions of the Stawell and Bendigo zones are mainly subsurface features based on gravity and magnetic data. The latest Silurian to Devonian Darling Basin in central western New South Wales is too thick for the relationships between the Stawell and Wagga-Omeo zones to be resolved from gravity and magnetic data.

Fig. 2. Image derived from gridded gravity data (Bouguer anomaly map) overlain by the extent of the magnetic anomaly associated with the subsurface Macquarie arc, distribution of plutons of the Boggie Plain supersuite (after Wyborn et al., 1986; White et al., 2001) and the extent of outcrop of the Macquarie arc. Map is restricted to southeastern New South Wales and northeastern Victoria (ACT = Australian Capital Territory). Map is compiled from data available from Geoscience Australia. Note the magnetic anomaly overlaps with a broad gravity high consistent with denser rocks forming a deep root to the Macquarie arc and also associated with the Boggie Plain supersuite granites.