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Linking accretionary orogenesis with supercontinent assembly

Peter A. Cawood [a,*], Craig Buchan [b,1]

[a] *Tectonics Special Research Centre, School of Earth and Geographical Sciences, The University of Western Australia,*
35 Stirling Highway, Crawley, WA 6009 Australia
[b] *Tectonics Special Research Centre, Department of Applied Geology, Curtin University of Technology, GPO Box U1987, Perth, WA 6845 Australia*

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Abstract

Age relations for assembly of Gondwana and Pangea indicate that the timing of collisional orogenesis between amalgamating continental bodies was synchronous with subduction initiation and contractional orogenesis within accretionary orogens located along the margins of these supercontinents. Final assembly of Gondwana occurred between *c.*570 and 510 Ma, amalgamating the various components of East and West Gondwana. This was coeval with a switch from passive margin sedimentation to convergent margin activity along the Pacific margin of the supercontinent. Timing of subduction initiation along the Pacific margin ranges from 580 to 550 Ma as evidenced by the first appearance of arc derived detrital zircons in the upper Byrd Group sediments and the oldest supra-subduction zone plutons along the Antarctic segment of the margin. A phase of extension marked by supra-subduction zone ophiolite generation at 535–520 Ma is preserved in greenstone successions in eastern Australia and overlaps the onset of Ross–Delamerian contractional orogenesis between 520 and 490 Ma, inboard of the plate margin that coincides with the cessation of collisional orogenesis between the amalgamating blocks of Gondwana. Supra-subduction zone igneous activity was continuous throughout this period indicating that subduction was ongoing.

The final stages of assembly of the Pangean supercontinent occurred between *c.*320 and 250 Ma. Major plate boundary reorganization during this time was accompanied by regional orogenesis along the Pacific margin. The East Gondwana margin segment experienced transpressional and transtensional activity from *c.*305 Ma until *c.*270 Ma, after which convergence along the plate margin was re-established. In eastern Australia this involved a migration of arc magmatism eastward into the old subduction complex indicating a stepping out of the plate margin. Synchronous with this phase of plate re-adjustment was the Gondwanide Orogeny (305–230 Ma) affecting the entire Pacific margin of Pangea.

Temporal relations across supercontinents between interior collisional and marginal accretionary orogenies suggest a linked history between interior and exterior processes perhaps related to global plate kinematic adjustments. Orogenesis in accretionary orogens occurs in the absence of colliding bodies during ongoing subduction and plate convergence and must therefore be driven by a transitory coupling across the plate boundary. Correspondence of coupling with, or immediately following, subduction initiation and plate boundary reorganization, suggests it may reflect plate re-adjustments involving a temporary phase of increased relative convergence across the plate boundary.

Keywords: Accretionary Orogen; supercontinents; driving mechanisms; Gondwana; Pangea; plate reorganization

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[*] Corresponding author. Fax: +61 8 6488 1090.
E-mail addresses: pcawood@tsrc.uwa.edu.au (P.A. Cawood), cbuchan@fugroairborne.com.au (C. Buchan).
[1] Current address: Fugro Airborne Surveys, 65 Brockway Road, Floreat, WA 6104, Australia. Fax: +61 8 9273 6466.

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1. Introduction

A fundamental question in tectonic studies of orogenic belts is *what drives orogenesis?* For classic 'collisional orogens' (Fig. 1a), where two continents have been brought together at the completion of a Wilson Cycle (e.g. Wilson, 1966), orogenesis reflects the resistance of a buoyant continental nuclei to subduction resulting in significant lithospheric thickening and deformation of both the upper and lower plates. However, in the case of *accretionary orogens* (Fig. 1b) the driving mechanism is less obvious because deformation, metamorphism and crustal growth take place in an environment of long-term subduction and plate convergence without the collision of continental blocks or large-scale buoyant lithosphere (Murphy and Nance, 1991; Windley, 1992; Sengör et al., 1993; Windley, 1993; Nance and Murphy, 1994; Sengör and Natal'in, 1996a,b). The lack of an obvious colliding body in accretionary orogens means that the driving mechanism of orogenesis must involve some form of transitory plate coupling which raises the question; *what mechanisms can increase coupling between plates within an accretionary orogenic system?*

The aim of this study is to establish the possible mechanisms of coupling by documenting the distribution and timing of orogenic events both across and laterally along an entire marginal orogen and compare these to orogenic events occurring in the same time period associated with amalgamation of cratonic blocks during supercontinent assembly. This will be achieved by reviewing and comparing the large volume of published geological, geochronological, geochemical and tectonic data of events related to the assembly of the supercontinents of Gondwana and Pangea with the Neoproterozoic to late Palaeozoic Terra Australis Orogen (Cawood, 2005) that was active along the Pacific margin of these supercontinents.

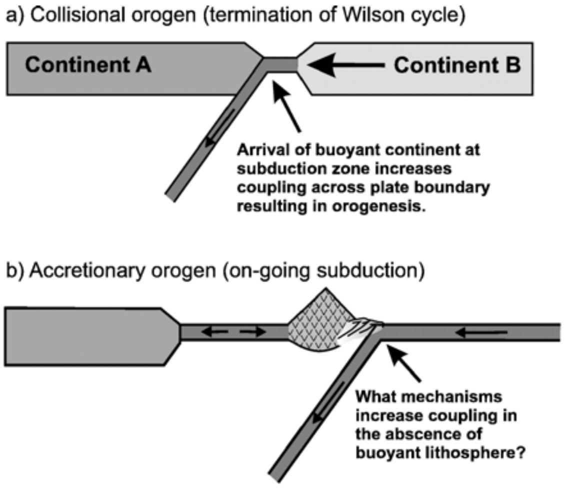

Fig. 1. Schematic diagram illustrating differences in tectonic plate interaction in collisional (a) and accretionary (b) orogens. In collisional orogens subduction of oceanic lithosphere will cease when the continents collide and crustal shortening of one or both continents takes place whereas, in accretionary orogens subduction is ongoing throughout orogenesis and shortening in the upper plate must be driven by coupling between the subducting and overriding plates.

This study demonstrates that the final stages of collisional orogenesis between the amalgamating blocks of the supercontinents were coeval with subduction initiation and accretionary orogenesis along the Pacific margin. Plate re-adjustments, caused by a change in relative plate convergence following cessation of shortening in the internal collisional orogens of the amalgamated supercontinents, provide a compelling means of driving increased transitory coupling across the plate boundary resulting in orogenesis.

2. Data selection and compilation

The tectonostratigraphic data presented in this study have been compiled from radiometric and palaeontological age data that are freely available in the published literature. The interpretation of the tectonic significance of the data was made using accompanying geochemical, structural and geological evidence. Emphasis was placed on distinguishing between an orogen and an orogeny; the former referring to the geographic extent of a tectonostratigraphic assemblage of rock units spanning an extended period of time that have been variably affected by one or more short-lived tectonothermal events, whereas an orogeny is a temporally specific tectonothermal event resulting in deformation, metamorphism and crustal thickening. The data have been sourced from a variety of isotopic techniques but, where available, U–Pb zircon data have been used for interpretation due to the more robust nature of this system that limits its potential for resetting during subsequent events. In those cases where less robust systems are the only data available, consideration of closure temperature and the potential for isotopic resetting by other means, such as deformation in the $^{40}Ar/^{39}Ar$ system, has been considered. The data are compiled in an un-filtered way in order to fully assess the level of coverage available.

Owing to the focussed nature of the current study, compilation has been restricted to two time intervals between 610 and 470 Ma, covering the time of Gondwana assembly, and 400 and 200 Ma, covering the time of Pangea assembly. For the period between 610 and 470 Ma some data for East Gondwana were sourced